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THE SCIENTIFIC MONTHLY

OCTOBER, 1934

BIOLOGY AND SOCIETY[1]

ANIMAL SOCIETIES

By Dr. WILLIAM MORTON WHEELER

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Τά τε ἐλάχιστα τῶν ζώων τὰς συνελείσεις αὐτῶν ἐν εἰρήνῃ καὶ ὁμονοίᾳ ποιοῦνται. (And the least of the animals enter into their associations in peace and concord.)—*Clement, Epistle to the Corinthians*, I, 20.

"Nicht einmal die Volksgemeinschaften, in denen überall der Klassenkampf tobt, tragen den Stempel mütterlichen Geistes, der allein aus den vielen Einzelgliedern eine wirkliche Volksfamilie schafft, wie uns die sozialen Insektenstaaten lehren." ("Not even the communities of nations, in which everywhere class-war rages, bear the imprint of the maternal spirit, which alone is able to create a true family of the people out of the many separate members, as we are taught by the social states of the insects.")—*E. Bergmann, Erkenntnisgeist und Muttergeist*, 1933, p. 275.

It is common knowledge that many infrahuman organisms, both plant and animal, live regularly in aggregations, associations or communities more or less like our own societies. The biologists' domain is supposed to cover the entire range of this "togetherness" behavior of whole organisms from Bacteria to Anthropoid apes, while the sociologist reserves for himself the study of human societies. We may be prepared, therefore, to find considerable divergence between the biologist's and the sociologist's points of view. I infer that I am to represent the biologists in this symposium, not because of any competency to synthesize what they have learned in so vast a field, but because of my long interest in a group of animals whose activities have always seemed, even to the most casual observer, to exhibit certain interesting resemblances to the social and political behavior of man. Instead, however, of dwelling on these resemblances, which, though interesting, are superficial and have become rather trite, I propose, after commenting briefly on the position of the study of organismal consociations among the biological sciences and the abundance and variety of these consociations, to consider at greater length some of the more fundamental social differences between the two dominant groups of animals, represented by the social insects on the one hand and the warm-blooded Vertebrates, man included, on the other. Though my argument will compel me to trespass on the preserves of the gentlemen who are to continue the symposium, I trust that my remarks will be received as offered in a spirit less dogmatic than their necessarily brief and abrupt exposition may seem to suggest.

[1] A symposium presented on the occasion of the celebration of the semi-centennial anniversary of the American Society of Naturalists at its fifty-first annual meeting at Harvard University on December 30, 1933.

During the nineteenth century biology and sociology developed in rather intimate symbiosis. Though Comte founded sociology on biology, it is well known that certain important conceptions, such as the struggle for existence, the survival of the fittest and the physiological division of labor, were derived from sociological sources and later extended to the entire world of organisms in the Darwinian theory of evolution. If we may judge from the works of Spencer, Espinas, de Lilienfeld, De Greef, Worms, Waxweiler and others, this theory, after its first clear enunciation, seems to have been more heartily welcomed and embraced by the sociologists than by the biologists. Subsequently, however, owing to the great opportunities for investigation, which had been opened up, in their respective fields, in the latter part of the nineteenth and the beginning of the present century, the biologists and sociologists drifted apart. The biologists specialized increasingly in the classification, morphology, physiology and genetics of the individual organism, while the sociologists seemed to lose much of their interest in biology and proceeded to ally themselves more closely with the psychologists, historians, economists and ethnographers. It was not till the recent development of ecology as an independent formulation of what had long been known as natural history that the study of plant and animal consociations acquired scientific status. This science has now been divided into autecology and synecology, the former concerned with the external adaptations of the individual organism, the latter with the plant and animal consociations. There are reasons, however, for regarding autecology as a department of general physiology and synecology as constituting the proper domain of ecology. At any rate, synecology seems to cover the same field as sociology in its broadest sense, or what might be called general comparative sociology, which would, of course, include not only human societies but also all the various consociations of plants as well as animals. Man will always be a mammal and his basic behavior will always be mammalian behavior. That he also exhibits other and very different activities justifies the recognition of human sociology as a special field, but so many of his so-called "spiritual" idiosyncrasies are now being traced to behavioristic rudiments among the primates that the biologist will look askance at all the attempts of the ideologists to sever, or even to stretch unduly, the bonds between his science and sociology (1).

A very brief survey will suffice to reveal the great extent and variety of consociative behavior in the animal kingdom. Indeed, there is no animal species that does not exhibit some such behavior, even if it fails to outlast the brief mating period or the temporary association of mother and offspring or amount to more than membership in some biocoenotic community. I find it convenient to classify all the animal consociations under seven heads. First, there are the loose and unstable populations known as aggregations, which consist of the same or different species and are very frequent among Protozoa, Invertebrates and cold-blooded Vertebrates. In many of the cases recently studied by Allee and others the individuals are assembled and kept together mainly by their tropistic or sensory responses to very local environmental stimuli, but others, such as the mating congregations of many insects, the migratory swarms of locusts, etc., arise in response to interindividual stimuli or to combinations of these with environmental stimuli. We should place in a second category the very different, compact and mainly nutritive consociations exemplified by the multicellular bodies of all Metazoan animals, the zooidal colonies of many Coelenterates, Bryozoans,

Tunicates, etc., and the series of metameres constituting the bodies of Annelids, Arthropods and Vertebrates, if, as many zoologists believe, these metameres are really serial, abortive zooids. The third category comprises the peculiar "food associations," consisting of individuals of two different species, of which one may be a plant, and exhibiting various kinds and degrees of intimacy as in the cases of predatism, parasitoidism, parasitism, commensalism, domestication, symbiosis, fungus-culture, the associations of mites, ants and beetles with certain peculiarly specialized plants, and the vaguer phenomena of myrmecochory, mimicry, etc. The food associations are so very numerous, diverse and economically important that they have been made the subject of an independent science, parasitology. A fourth category comprises the flocks and herds of the birds and mammals, and include as their most highly developed examples the troops or bands of monkeys and Anthropoid apes. A fifth category would comprise the insect societies, both temporary (subsocial) and permanent. The number and diversity of the latter are very great, since there are fully 10,000 species of social insects, each of which may be said to have its own peculiar pattern of social behavior. To the sixth category I would assign the human societies and to the seventh the biocoenoses, or what the ecologists call "communities," those consociations of animals and plants of various species, attached to particular ecological environments, such as the interdependent faunal and floral elements of a forest, cave, desert, stream, sand dune, etc. These communities are so complex, unstable and difficult of definition that their adequate analysis seems to be impossible with our present biological methods. The totality of existing biocoenoses may be said to constitute one great super-biocoenose, embracing all living organisms, man, of course, included, and equivalent to the biosphere, or thin, more or less discontinuous film of living matter covering the lithosphere and pervading the hygrosphere of our planet.

Some authors have referred all the heterogeneous consociations I have enumerated to a single "cause," variously designated as the "social," "gregarious" or "herd instinct," but this is mere animistic verbalism. That a consociation can have no single "cause," but is determined by a set of conditions, and that each of the many consociations is determined by its own set of conditions would seem to be inferable from the following considerations:

(1) The various consociations, as patterns of group or mass behavior, are obviously so many forms of adaptation, or "adaptates," to use a term invented by the sociologist Tarde. And while we may, perhaps, recognize homologous consociations among taxonomically closely related species, we agree with Ward and Petrucci that at least the more complex and dissimilar types represent independent, polyphyletic and therefore merely analogous, or convergent adaptates. This seems also to be true of many similar consociations, so that no classification of the types or forms of societies can be a "natural" classification, nor coincide at all closely, except within the narrow confines of families or genera, with our morphological or taxonomic classification. I am convinced that during the long phylogenetic history of the Insecta alone very similar types of societies have arisen quite independently from the mother-offspring relation on more than 30, and in the Aculeate suborder of Hymenoptera alone, on at least 7 different occasions, but in each case more conditions than the mere mother-offspring relation must have cooperated to determine the complete societal pattern.

(2) The futility of accounting for consociative behavior by referring it to

a special social instinct is shown also by the fact that every consociation is a more or less integrated, spacio-temporal system, or emergent, consisting of a number of lower level emergents. This is clearly seen in the case of insect and vertebrate societies, which are really so many epitomizations (2) of many forms of consociative behavior like those exhibited by the multicellular individual, the aggregation and pairing of individuals, the family, with its parent-offspring relations, the food associations (predatism, parasitism, symbiosis), etc. Such components necessarily undergo great deformation, or take on quite novel aspects in the final synthesis, represented by the insect or mammalian society. In human society, of course, the creative psychological factors introduce even more extraordinary complications. In all cases, however, we are dealing with what the philosopher G. H. Mead (3) had in mind when he defined sociality as "the capacity of being several things at once."

Insect and mammalian (including human) societies have a peculiar interest because they happen to represent the highest types of behavior to which the two most important animal phyla, the Arthropoda and Chordata, have attained. Of course, the differences between these phyla are enormous, as is evident from the disparity between their members in size, structure, longevity and behavior. I shall confine my remaining remarks to one of the most outstanding differences and one that seems to me to be of no little interest in connection with our own social organizations, namely, the high degree of integration and stability of the insect society and the extraordinarily harmonious and self-sacrificing cooperation of its individual members, as contrasted with the mobility, instability and mutual aggressiveness so conspicuous among the members of our own society. Moralists, inventors of Utopias and satirists have never allowed us to forget the ants and the honeybees, because they actually enjoy what is, perhaps, for us poor humans only a social ideal. Until recently the termites were not mentioned in this connection, partly because they were supposed to be ants and partly because their monumental social achievements are confined to the tropics, where the best is like the worst and uplift is unpopular.

Although it has long been known that the social insects are, as a rule, extremely aggressive towards the individuals of other communities, even of the same species, little search has been made for the conditions that have brought about the harmony between the individuals of the same community (4). This is obviously only one of the aspects of the great stability of the social system and the result of a very long history. The numerous fossils now amassed in our museums show clearly that all the main groups of social insects had completed their social organization, their caste differentiation and to a considerable extent also their taxonomic evolution by the beginning of the Tertiary (Eocene and Oligocene), some 50 to 60 million years ago. They must have begun their social organization, therefore, somewhere in the Cretaceous, if not earlier, perhaps as long ago as 80 or 100 million years. Hence, if the age of our own species is put at not more than a million years, we might be tempted to condone the instability and aggressiveness of our societies as expressions of social infantilism or immaturity, but mere time and the fact that the social insects have at least thirty generations to our one can be significant only when taken in connection with the underlying behavioristic peculiarities that made for social stability or instability in the first place. The important difference lies, I believe, in what I shall call the "problem of the male," which has been successfully solved by the social insects but

not by mammal or human societies. The social insects, in fact, solved the problem by two different methods, one of which was employed by the social Aculeates (ants, bees, wasps), the other by the termites.

For obvious biological reasons the female is the social sex *par excellence*, whereas the male was originally and remains throughout the evolution of the Arthropod and Chordate phyla, except in a few fishes, amphibians and birds, the unsocial sex. In many animals, in fact, he might more properly be called the antisocial sex. When the individuals of a species discovered in social organization a new and powerful adaptation to the environment and to one another, the male as a necessary fecundating agent could not, of course, be completely ignored, but his original constitutional differences in the two phyla resulted in corresponding differences in his social assimilability. Among the insects this is clearly seen in the exclusively female societies of the social Aculeates, all of which are really so many taxonomic families of wasps, derived without doubt from solitary wasps of the superfamilies Vespoidea and Sphecoidea. These, in turn, we regard with equal assurance as being descended from the Parasitoid or Terebrant Hymenoptera, which had evolved as early as the Jurassic, some 150 million years ago (as shown by the fossil *Ephialtites jurassicus*), and are still represented in our recent fauna by thousands of species. Now throughout the Terebrant suborder and the solitary Vespoids and Sphecoids we find that the female is larger, more muscular and generally more richly endowed than the male and exhibits an intricate behavior pattern in providing for her offspring, while the male has reduced mouthparts, less specialized antennae, a smaller, less differentiated brain, except for its optic ganglia, and a behavior pattern so meager as to amount to a mere seeking out and fecundating of the female. As if to increase his inferiority complex, the female acquired the capacity to produce viable offspring from unfertilized eggs and developed a muscular-walled spermatheca for the storage of the spermatozoa from a single mating, with glands producing a secretion to keep them alive for several weeks. When certain families of solitary wasps became social, therefore, it was easy to exclude the males from participating in the communal activities and to tolerate them about the nest only in small numbers and for a brief annual season. By enlarging the spermatheca enough sperm from the single mating could be stored and kept alive for months or even years—three or four years in the honeybee, three or four times as long in the ants—to fertilize thousands of eggs. Having solved the problem of the male by reducing him, so to speak, to an appropriated and stored convolute of sperm, the social Aculeates, long before the Tertiary, proceeded to introduce new styles of females by inhibiting the development of the ovaries in the majority of the offspring, which thus became the workers. These were still further diversified in many species of ants as soldiers, or defenders, and workers proper, or nurses and nest-builders. The division of labor thus initiated was utilized in overfeeding and thereby exaggerating the fecundity of the fertile female, or queen, and the rearing of more and more of the sterile individuals to build the nest and feed, rear and defend the successive broods.

The termites, because of their very different phylogenetic origin, solved the problem of the male in an even more satisfactory manner than the social Aculeates. They are closely related to the cockroaches, or Blattoids, and probably branched off sometime during the Mesozoic from the ancestors of the latter, the extinct Protoblattoids. Like the Blattoids the termites have a very in-

complete metamorphosis, their sexes are externally very much alike, and the spermatheca of the female, which is non-parthenogenetic, is more rudimentary than in the social Aculeates and lacks spermophilous glands. These peculiarities, inherited no doubt from Protoblattoid ancestors, seem to account for the fact that the societies of the termites are bisexual instead of female, as in the social Aculeates. The termitary is founded by a male and a female, or king and queen. The king cooperates with his consort in excavating the initial chamber in the soil or dead wood and, being a long-lived insect, continues to live at her side, mating with her from time to time and thus enabling her to produce enormous numbers of viable eggs, which in some African species may be laid at the rate of 30,000 a day. The nymphs hatching from some of the eggs are fed in such a manner as to become kings and queens, which will either found new colonies or eventually take the places of the deceased royal parents of the termitary, but the great majority of nymphs become male and female soldiers or male and female workers, in approximately equal numbers, because their reproductive organs are aborted as in the exclusively female workers and soldiers of the social Aculeates. The termites therefore keep only a single fully developed, monogamous male in the termitary and, as if confronted with a serious problem of male unemployment, have hit upon the happy device of sterilizing most of the nymphs of this sex in their infancy and setting them to work with their equally sterile sisters in the kitchens, dining rooms and nurseries and at building and defending the termitary instead of permitting them to sit around like a lot of social parasites and annoy the females. We may say that the termites are the only animals that have succeeded in completely socializing their males.

Until recently we had little accurate knowledge of the bird and mammal flocks, herds, packs, troops or bands, collectively designated by Espinas as "peuplades." Their organization proves to be very different from that of the social insects, because the individuals among the higher Vertebrates are much more highly differentiated than they are among the insects and other Invertebrates. The rôles of the sexes, too, are more specialized. This is especially true of the male, which in the higher Vertebrates is usually larger, stronger, more restless, more inquisitive, more exhibitionistic, bolder, more reckless, more brutal, more pugnacious and less sagacious than the female. He eventually becomes, therefore, a much more serious social problem than he is among the insects. Indeed, he acts like a violent ferment in Vertebrate group life, increasing both its constructive and destructive mobility and accentuating its dynamically stratified organization.

We may select as a paradigm of Vertebrate Society Schjelderup-Ebbe's account of a flock of domestic fowl (5). Close observation shows that every bird in the flock is a personality, determined by its ambivalent dominance-submission reactions in relation to every other bird. Thus bird A can peck bird B and B can peck C, etc. An alien fowl may enter the flock but acquires a definite status or relationship to the other birds only after demonstrating its abilities as a pecker and the extent to which it is resigned to being a peckee. Schjelderup-Ebbe calls the hierarchy of status, which I have briefly described, the "pecking order." There may be one individual, the "α-bird," usually but not necessarily a mature cock, which has the right to peck every other bird, but there is obviously no ω-bird, unless we apply the term to a dead bird. The pecking order, however, is far from being a fixed and constant hierarchy. It is really very complicated, because the interrelations of the birds are often triangular or

polygonal, A pecking B and B, C, but C may be able to peck A, or the series may be ABCDA with a resolution of the rectangle into triangles, ABCA, BCDB, etc. Furthermore, the order is constantly changing with the changing physiological state, or age, vigor and health of the individual birds. The diseased, disabled and aged soon descend through the ranks of peckees, while the young, after a long submissive rôle, promote themselves as rapidly and as far as their strength and pugnacity will permit to the ranks of peckers. Schjelderup-Ebbe noticed that the higher the birds stood in the pecking order, the better their general health and the more self-confident their behavior seemed to be, while those of the lowest rank wore a dejected and bedraggled appearance.

The organization of the herds and packs of the lower mammals is like that of the bird flock, except that we should have to call it a biting instead of a pecking order, or with recent students of mammalian behavior a "scale, or order of dominance." As long ago as 1892, Hudson in his "Naturalist of La Plata," writing of the packs of semiferal dogs kept on the cattle-breeding establishments in Argentina, remarked that "from the foremost in strength down to the weakest there is a gradation of authority; each one knows just how far he can go, which companion he can bully when in a bad temper and wishes to assert himself and to whom he must humbly yield in turn." A dominance scale of fundamentally the same type has been observed in the troops of various monkeys and anthropoid apes but is, of course, more elaborate, as we should expect from the greater physical and psychical plasticity of these creatures. It is scarcely necessary to emphasize the fact that in man the very ancient mammalian dominance scale has not only persisted, but has become even more highly differentiated than in our primate ancestors. We are all born into such an order, the family, and all our institutions—governments, armies, navies, schools, churches, business-houses, factories, etc.—are so many magnificent pecking orders, which condition and regulate our lives and keep our emotions oscillating between elation and misery, according to the position we happen to be holding within them (6).

In order to bring my argument to a conclusion something more must be said about the mammalian male. When mature he naturally occupies a higher rank than the female in the dominance order of the group. Owing, however, to the decidedly unsocial character of his behavior, which manifests itself almost exclusively in voracity, pairing and fighting with other males, he is always, so to speak, socially more or less indigestible. There seems to be no reliable record, at least among the lower mammals, of a male providing food for the female or young or even protecting them. Indeed, after pairing, the sexes seem to become indifferent or even hostile to each other and the female retires to bear, suckle and rear her young in a safe lair or retreat which she alone establishes. She thus forms a family with her young of both sexes and in advanced life may become the leader of a herd consisting of several such female-offspring families (ruminants, elephants, cetaceans, etc.). Here the social organization unmistakably resembles that of the social Hymenoptera, since the male is not a member of the family (7). Even in mammals as high in the scale as bats the two sexes form separate peuplades. Such social ties as the males of these and other mammals exhibit among themselves may be due to social conditioning while they are still young and under the tutelage of their mothers. In the seals and more conspicuously among the apes, as shown by Zuckerman's observations on the troops of baboons (8), and the scattered published

accounts of the anthropoids, the adult males are found definitively installed within the group and giving full expression to their dominance (9). In the troops of baboons each of the mature males, the "pashas" or "overlords," secures as many mature females as possible to form a harem, which he carefully guards and to the outskirts of which the younger and less dominant bachelors attach themselves. As soon as the pasha's vigor declines, they snatch away the females and set up as pashas on their own account. A troop of baboons is, therefore, far from being an urbane and amiable society. The unsocial character of the male reveals itself even more clearly, both among the lower mammals and the Anthropoid apes, when he becomes senescent and impotent and wanders away from the troop or herd to lead the life of an anchorite "rogue." The female, on the contrary, as a virago, acquires a certain male dominance and becomes the matriarch of the herd without serious loss of her social interests.

At first sight human society seems to have solved the problem of the male. At any rate, the reader of many sociological treatises is left with the impression that human groups are uniformly, bisexually socialized throughout. Certainly the majority of men are far more social than the male apes. We have, unfortunately, no knowledge concerning the origin of the human species or of the social rôle of the sexes in its earliest groups. Although authorities agree that none of our extant anthropoids can be in the direct line of man's descent, there is considerable difference of opinion in regard to the point of divergence of his immediate ancestors from the hypothetical primate stock. Some believe the divergence to have taken place as early as the Oligocene, others not till the Miocene, and then from some common ancestor of the chimpanzee and gorilla, while at least one author regards man as a polyphyletic species, derived from several hypothetical primates, each of which gave rise to one of the extant species of anthropoids. Although the character of man's earliest social organization is unknown, the researches of ethnographers, archeologists and historians show that it was in all probability what it still is, a dominance order, or what Sorokin calls a "social stratification," resembling that of the birds and mammals (10). The great physical energy and unequal endowment of the individuals within this order and especially the predominance of the males evidently accounts for the extraordinary restlessness and mobility of human societies (11). Even in primitive human societies there must have been far more cooperation between the sexes than there is among the higher mammals. This cooperation may have had its origin, as Zuckerman suggests, in a division of labor between the sexes at the time when man changed from a vegetarian to a largely carnivorous diet (12), but it seems to me that the pronounced socialization of the male must have been due in great measure to the intensive social conditioning to which he was subjected by the mother and the other members of the family during his infancy and childhood, which are so much longer than in other primates. One is tempted also to look on the matriarchal, or matrilineal type of human society, which, according to many ethnographers, was once universal and still survives among many peoples, as eminently suited to socializing the male. Even in these societies there is a clear division of labor between the sexes, since the males do the heavy work, hunting and fighting, and also function as chiefs and shamans (13).

Be this as it may, however, the male has now become so dominant in our modern patriarchal societies that we may regard them as male societies in contradistinction to the female societies of the Hymenoptera and lower mammals and the bisexual societies of the termites. Furthermore, the manifesta-

tions of this dominance show clearly that the human male has never been adequately socialized. Throughout the ages the aggressive, emotional instability, intense egoism and pugnacity, not to mention other unsocial and antisocial tendencies inherited from his Anthropoid ancestors, have kept society in constant turmoil, so that human history is little more than an interminable record by sober and impressionable males of the abominable behavior of other males. We might, perhaps, divide the members of this sex very roughly into three classes. One of these, the majority, comprises the completely socialized individuals who, in collaboration with the women, maintain the social structure. The second class is very small and comprises less socialized individuals whose dominance is manifested mainly in the intellectual and emotional fields. These males really constitute two ill-defined subclasses, one of which may be said to create the great cultural values (sciences, arts, technologies), the other the great cultural illusions (philosophies, theologies, social utopias). To the third class we may assign a not inconsiderable number of criminals, or individuals of low mental age and with unbalanced endocrines, who in the past have succeeded in wrecking every great civilization. We have all been witnessing recently such an extraordinary display of antisocial behavior by males of this class in continental Europe, the Orient, Cuba and the United States, that further comment is unnecessary.

After I had written the first draft of this paper, I was pleasantly surprised to find that I must have been in somewhat belated telepathic rapport with Professor Ernst Bergmann, of the University of Leipzig, who very recently developed essentially the same thesis, with much greater eloquence and erudition, in a fascinating book entitled "Erkenntnisgeist und Muttergeist" (second edition, Breslau, 1933). He has, in fact, constructed a grandiose "sociosophy" of the sexes out of materials drawn from the remotest by-ways of religion, ethics, philosophy, history and biology (14). I should differ with him, perhaps, in placing more emphasis on the fact that all progress in our civilized societies is initiated by a relatively small portion of the male population, whose restlessly questing intellects are really driven by the unsocial dominance impulses of their male mammalian constitution and not by any intense desire to improve society. Female societies, like those of the Hymenoptera and lower mammals, and bisexual societies, like those of the termites, are indeed peaceful and harmonious, but also stationary and incapable of further social evolution (15). Even the matriarchal clans of primitive man advanced towards civilization only after they had become patriarchal (16). We seem to be confronted with the trilemma of either finding some means of socializing our males more completely, or of returning to a more unprogressive bisexual society like that of the termites (Russia already shows a suspicious approach to such a society), or of lapsing into something like Spengler's Fellahin society. For thousands of years attempts have been made to socialize the unsocial and antisocial males by fasting, prayer, sermonizing, systems of ethics, idealistic philosophies, legislation, prohibition, punishment and discipline, but with very indifferent success. It is always in order, of course, to suggest a thoroughly reorganized mental and physical education of the young as a cure for our social ills (17), but it is equally probable, as Bergmann insists, that only an adequate knowledge of the biology and psychology of the sexes will enable us to solve the problem of the male. Fortunately, the youthful sciences of endocrinology, genetics, eugenics, penology and psychiatry are beginning to provide us not only with this knowledge but also with suggestions for its practical application.

NOTES

(1) Certainly the fact that there are many weaknesses in the organicist analyses of the earlier sociologists, as Keller, Ferrière, Sorokin and others have shown, is no excuse for the modern sociologist's lack of interest in the animal consociations. Recent investigations, some of which are briefly considered in this article, are showing with increasing clearness that the sociologist can still derive valuable suggestions from infrahuman group phenomena. Not only does individual animal behavior prove to be much more subtle than the earlier zoologists supposed, but animal groups exhibit many activities that are very difficult or impossible of analysis in human societies. The animal groups are not only more numerous and more diverse and therefore more richly illustrative of many patterns of social behavior, but also more sharply delimited in space and time than primitive human societies. The animal consociations also possess other methodological advantages, since they can be isolated, their personnel controlled at will and their behavior subjected to experimental investigation. Their shorter life-span, moreover, enables us to study their origin and growth, their pathology and eventual extinction.

The extent to which Sorokin would allow the sociologist to adopt an organicist view of human society is indicated in the following quotation ("Contemporary Sociological Theories," Harper Bros., N. Y., 1928, p. 207): "In bio-organismic theories we must strongly discriminate between two different classes of statements. The first class is composed of the statements that sociology has to be based on biology; that the principles of biology are to be taken into consideration in an interpretation of social phenomena; that human society is not entirely an artificial creation; that it represents a kind of living unity different from a mere sum of the isolated individuals. These principles could scarcely be questioned. They are valid. They are shared, however, not only by the bio-organismic school, but by a great many other sociological schools. In this sense they do not compose a monopoly of the bio-organismic theories, or their specific characteristics."

(2) With the meaning of the term as employed by G. P. Conger in his "A World of Epitomizations," Princeton University Press, 1931.

(3) "The Philosophy of the Present," Open Court Publishing Co., 1932, p. 49.

(4) Exceptions to the latter statement are the slaughter of the drones and the battles between old and young queens in the honeybees, the slaughter of the soldiers by the ant *Pheidole militicida* and apparently also by some termites, the destruction of their own brood by wasps and ants, the devouring of portions of their young brood by colony-founding queen ants and the assassination of the nest queen by her own workers and the adoption of a parasitic queen in her place by some host ants. All these cases, except the last, are motivated by the failure of the food supply at certain times or seasons and are really attempts to preserve the life of the colony. The last case, according to Forel, is due to the preference of the workers for a small, young and very fecund queen instead of their own large mother, because the latter demands more food. Perhaps, however, other attractions of the parasitic queen, such as agreeable secretions, which, like those of some myrmecophilous beetles, tend to pervert the appetites of the workers, may be the true reason for adoption. We are, nevertheless, dealing with a distinctly pathological condition.

(5) T. Schjelderup-Ebbe, "Die Despotie im sozialen Leben der Vögel." Arbeit. biol. Grundlegung der Soziologie, Hirschfeld, Leipzig. X, 2, pp. 77–140.

(6) Notwithstanding the development of dominance in man it seems only occasionally to have attracted the attention of sociologists and psychologists till recently. In social psychologies it was often briefly treated as the "instinct of self-assertion" till those *enfants terribles*, the psychoanalysts, and especially Adler, began to rear an imposing doctrine upon it. Now we are all familiar with the exaggerated or pathological manifestations of dominance—the superiority complex, self-maximation, the regal self, the Jehovah-complex, the Messianic complex, the God-complex, the masculine protest, exhibitionism, sadism, etc. Its more temperate, normal aspects certainly did not escape some of the philosophers, such as Hobbes, Schopenhauer, Nietzsche, Hocking and Spengler, but their pet term—"the desire for power" or "the will to power"—and those of the moralists, psychologists and historians—egotism, egocentricity, self-interest, ambition, emulation, competition, elation, aggressiveness, greed, pride, vanity, display, authority, prestige, coercion, supremacy, dominion, tyranny, conquest, oppression, sovereignty, despotism, militancy, etc.—are so familiar that they lack the thrill of those fine psychoanalytical terms. Several social psychologists—McDougall, Tansley and others—regard dominance or self-assertion as an "instinct" and contrast with it another "instinct," "self-abasement," variously designated also as submission, subjection, subordination, allegiance, subservience, obedience, compliance, inferiority complex and masochism. If we regard dominance as an instinct it is certainly one so primitive and fundamental as to characterize all living substance and to be equivalent to self-preservation. Seneca said "*vivere militare est*," which is paraphrased by

Ortega y Gasset when he defines life as "the struggle, the effort to be itself." Adler admits that "the will to self-determination in the narrower sense, *i.e.*, to power, is a mental factor which . . . derives from far down in the animal world." Spengler, in his "Man and Technics," expresses the same thought more explicitly when he says: "The free-moving life of the animal is struggle, and nothing but struggle, and it is the tactics of its living, its superiority or inferiority in face of 'the other' (whether that 'other' be animate or inanimate Nature), which decides the history of this life, which settles whether its fate is to suffer the history of others or to be itself their history. *Technics is the tactics of living;* it is the inner form of which the procedure of conflict—the conflict that is identical with Life itself—is the outward expression." Curiously enough, Ellwood ("Sociology in its Psychological Aspects," D. Appleton and Company, New York and London, 1912, p. 228) regards the "instincts" of self-assertion and self-abasement as "peculiarly human." At this point we naturally ask whether it is possible to distinguish at all clearly between self-preservation of a living and that of any stable physicochemical system. Whereupon the consideration that mere existence necessarily implies some degree of self-preservation or self-maintenance at once lands us in the cactus-thickets of philosophy. We all at times experience the "pure-cussedness" of inorganic bodies and feel a dim mental affinity with the animistic savage. And what is "instinct," as employed in most biological and psychological literature, but camouflaged animism? Others are very doubtful whether there is a special instinct of self-abasement. "From the beginning," A. H. B. Allen ("Pleasure and Instinct," Harcourt, Brace and Company, New York, 1930) says, "every living thing has only existed by asserting itself and refusing to give way to others," and submission is imposed by the superior force of the dominant organism. "It is always possible to yield in a combat; and the yielding can hardly be called a separate instinct." "Submission is nothing but the negative of self-assertion; it is the giving up of self-assertion, accompanied by the opposite feeling, that of pride negated or taken down." Moreover, it has not been demonstrated that self-abasement is innate, though in its pathological form, as masochism, it is accompanied by a positive feeling of pleasure. Other emotions such as fear may also accompany submission. C. R. Carpenter, one of the younger behaviorists, regards both dominance and submission in the black howler monkeys of Panama as merely positively and negatively conditioned reflexes and hence as learned reactions, or habits. That this opinion may be correct is indicated by the phenomena of domestication, which depends on man's dominance and the animal's submissiveness. In some of our domestic animals this submissiveness has to be secured by renewed "training" in each generation, in others it may require only a slight reconditioning of the animal's juvenile behavior.

(7) A few writers (*e.g.*, Jennings) do not regard the mother-offspring group among ants, bees, etc., as a family, probably because it contains no father. They seem to understand the term only in the derived juristic sense of the Latin *familia*, which stresses the presence of the male progenitor (*paterfamilias*) who is not like the mother "*naturâ vera et certa*," but "*jure verus et certus*," that is, a legal fiction. Originally the term *familia* meant the servant body of a household and has since acquired numerous meanings (see Century Dictionary). Since a widow and her children are called a family, objection to using the same term for the mother-offspring group of the social insects and lower mammals would seem to be mere quibbling.

(8) S. Zuckerman, "The Social Life of Monkeys and Apes," New York, Harcourt Brace and Company, 1932. For data on the anthropoids see R. M. and A. W. Yerkes, "The Great Apes," Yale University Press, 1929.

(9) Male dominance may have many different expressions. Even the voice may become an implement of this urge. The vertebrate male must have discovered long ago that his voice was more powerful and terrifying than that of the female and that he could often employ it effectively without endangering his hide. His voice proved to be particularly useful when his possessions were disputed by other members of his group. This is seen in many Vertebrates ranging all the way from the growling dog guarding his bone, the male song-bird preempting his breeding territory and the male howler monkey preempting the feeding area of his troop to the dogmatic, hortatory theologian defending his knowledge of the supernatural and the vociferous political orator defending his equally fictitious knowledge of economics and state craft.

Another interesting aspect of dominance in an extreme and sadistic form is exhibited in the courtship and mating behavior of animals. Major R. W. G. Hingston has made much of this aspect, which he calls "hostility" in his recent book, "The Meaning of Animal Colour and Adornment," London, E. Arnold and Company, 1933. I quote a few paragraphs (pp. 325–326) from the conclusion of his thirteenth chapter: "The sex act is a double act. It consists first in an act of male rivalry, second an act of sexual union. The two are interlinked and the second is dependent on the first. In all animals there occurs a preliminary rivalry—by

physical battle or threatening gesture or vocal utterance—before actual union is fulfilled. Often this rivalry is fierce and continuous. Several species have special assembling-grounds where the males come together for the sole purpose of developing this first stage in the act. The usual view of all this fighting is that it takes place for the possession of the females or the holding of breeding territories, and these undoubtedly are manifest results of it. But I am confident that, apart from these results, it fulfils a biological necessity of far deeper and wider significance. Is it likely that male animals would keep special arenas for the purpose of going through elaborate gesticulations or would indulge in long singing-contests unless their emotional natures demanded that there must be an outlet for their developing passions?

"All this rivalry then is of deep importance. And its importance, I believe, lies in the fact that it brings to full development that hostile emotion which is the first step in the act of coitus. This hostility is directed to the rival male; nevertheless, it is a fundamental step in the development of capacity for fertile union with the female. Rivalry does not occur just because a rival is present; I believe it must occur if full sexual activity is to develop. Rivalry and coitus are biologically interdependent; the one must be developed and brought to perfection in order that the other may be fully efficient. Indeed, I regard the act of coitus as the final step in the act of battle. It is, as it were, a demonstration to the male of the final achievement of his hostile intentions, satisfying all that he has battled for so intensively and standing in his emotional nature for the defeat and annihilation of his rivals. The sex act is then not a mere male-female contact, but rather an act of fierce hostility directed for a time against rivals of the same sex and receiving complete fulfilment through an act of union with the opposite sex. But fundamentally and all through the sex act has a hostile content.

"This view will later throw light on so-called courtship behaviour and on the important problem of sterility. Also it will help us to understand why the generative organs have this dual function. The testes not only secrete the sperm, but also control the fighting machinery. Why should these two functions be allocated to one organ unless the two functions were closely interknit in the fulfilment of the generative act? And on our view they are interknit, in that the efficiency of the sperm-producing function depends on the fulfilment of the act of battle."

(10) P. Sorokin, "Social Mobility," Harper Bros., New York, 1927. "Any organized special group is always a stratified social body. There has not been and there does not exist any permanent social group which is 'flat' and in which all members are equal. Unstratified society, with a real equality of its members, is a myth which has never been realized in the history of mankind. This statement may sound somewhat paradoxical and yet it is accurate. The forms and proportions of stratification vary, but its essence is permanent, as far as any more or less permanent and organized group is concerned. This is true not only of human society, but even in plant and animal communities." The term "stratification" is unfortunate, perhaps, in that it suggests a rigid or static order. Professor Sorokin, of course, makes it abundantly clear in his book that he is dealing with a dynamic organization.

(11) The greater physical energy of human individuals compared with those of other animal species is significant. As Pitkin says: "Man has built up, through the ages, a huge fund of physical energy with which to maintain himself against the hostile forces of his environment. He possesses more than three times as much, for each pound of his body weight, as any other mammal which has yet been measured. For each pound of flesh in a horse, cow, dog or cat, there is considerably less driving power through adult years than there is in five ounces of human flesh. (The exact ratio seems to be 2: 7.75, according to Rubner.)"

(12) Zuckerman, *loc. cit.*, p. 316: "At its lowest level, according to most authorities, the family of human society was monogamous. If reason played a part in determining the nature of the human family unit, it is very probable that it was guided by the demands of man's omnivorous diet. The polygynous gorilla or baboon can guard his females from the attentions of other males while they forage together for fruits and young shoots. Primitive man, who, as his Palaeolithic arts display, was an animal largely dependent on a diet of meat, would not have gone hunting if in his absence his females were abducted by his fellows. Reason may have forced the compromise of monogamy."

(13) *Cf.* R. Briffault, "The Mothers," 3 vols., London, 1927; abridged edition in one volume, Macmillan, 1931, and J. H. Ronhaar, "Woman in Primitive Motherright Societies," Holland and London, 1931.

(14) Bergmann follows a German convention which seems to require the academic philosopher to write and lecture in a Dionysiac style. In the following translation of an average passage (pp. 130, 131) I have preserved the meaning, but have been unable to prevent the temperature from dropping several degrees below that of the original. I have relegated it to a footnote, because it seemed still too warm for presentation to a male scientific gathering. "And we shall always have to

maintain that the tragic fundamental tone of the male's dramatic, ambiguous, exposed and precarious existence, based as it is on struggle and the elimination of his rivals, will forever prevent the emergence of a sane and happy communal life as displayed in the consummate victory of the maternal spirit, the joyous order and exuberant will to service of the social Hymenoptera. Of all this, indeed, little enough is to be seen in our modern social state, which is created and motivated by the awful splendor and grandeur of the male sexual tragedy, which manifests itself objectively in a perpetual war of the classes, in strife and masculine competition, and subjectively in the restlessness and conflict arising from the cravings and vital anxieties of the male sexual impulses, which are continually gnawing at the social order and hastening its break-up. Men created history, says Mussolini. We answer: Certainly but what kind of a history! One written in blood and tears. Men created religion. Certainly, but what kind of a religion! Thousands of years of contemplation of the hereafter, inspired by worldly anxieties and dread of death. Men created the state. Certainly, but what kind of a state! A strange, misbegotten, anti-state, without vitality, a compromise-and-bastard state that follows neither the life plan of the sexes, nor a just apportionment of the sexual rôles, nor motherright. And the peculiar tragedy of the human race evidently lies in the fact that the female sex never will and never can create history, religion or a state. If the masculine spirit of intellect and leadership does not itself initiate a great change in human culture by transcending the constitutional male idiosyncrasies and by a true interpretation of the cultural trends of religion, morals and the state in obedience to the basic biological requirements, then, *finis humanitatis!* The signs of the times seem to point to a change but they can be correctly interpreted only with the aid of the key-science, which is the sociosophy of the sexes."

(15) The insect societies might be called centripetal as contrasted with the centrifugal societies of vertebrates. The stability and high integration of the former are symbolized by the nest, which in all its forms—formicary, vespiary, apiary, termitary—is a communal "Gestalt," a unitary, organized whole peculiar to the species, though constructed piecemeal by the sterile members of the colony. Somewhat similar structures are made by a few birds but not by mammals, because each female makes and occupies her own lair or burrow. Our cities with their separate family dwellings or apartments are not, therefore, strictly comparable with the nests of the social insects. This is true even of the communal houses of certain savages.

(16) "The mother-family came naturally to be, by spontaneous growth out of antecedent conditions. The mother-clan persists indefinitely without any interruption, unless it dies out entirely. A father-family, on the other hand, necessarily breaks up every three or four generations at longest. The former is stable and enduring, like the sex upon which it is based; the latter is active and variable, prone to movement, raiding and eventually to conquest. In its broadest features the mother-family is conservative, traditional and tends to equality in many respects, whereas the father-family is enterprising, progressive, sets free individual energy, and therefore promotes inequality.

"The limited communalism of the mother-family, chiefly as respects food, wastes capital where it does not prevent its accumulation; the energy of men is not stimulated. Its garden-culture by women is only a premonition of agriculture; tillage proper does not begin until men take it in hand. The mother-family has little history, because its character is a perpetuity of sameness. There is slight division of labor in it and therefore little societal organization. It is exogamy and the father-family which begin competition, combination, cooperation and organization. The evolutional movement which we call progress gains momentum with the father-family. War under the mother-family is caused by bickerings over emplacement and blood-revenge; captives are killed or tortured and only exceptionally adopted or enslaved. War has the character of raiding merely. In the father-family, war is less impulsive and is more organized and planned for a purpose by the authority on the ground, and is prosecuted more perseveringly. Its purpose is plunder and, at length, conquest, and its results subjugation, domination, enslavement and eventually the construction of territorial states. Slavery is the connecting link between the economic and militant forces in the evolution of society. Since family organization moves at the same time through the change which we are now viewing, the total organization of society undergoes a transformation which is difficult to embrace and understand with due allowance for all the elements in it."—W. G. Sumner and A. G. Keller, "The Science of Society," New Haven, Yale University Press, 1927, Vol. III, p. 1984.

(17) For an interesting account of the proposals of philosophers and educators see Will Durant, "Philosophy and the Social Problem," the Macmillan Company, New York, 1917. A very suggestive approach to the philosophical biologists' view of ethics is given in Trigant Burrow's "Crime and the Social Reaction of Right and Wrong," *Journal of Criminal Law and Criminology*, 24, 1933, pp. 685–699.

THE BIOLOGY OF PRIMITIVE HUMAN SOCIETIES

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IT seems to me that many of the main trends of scientific studies are peculiar —not to say perverse. The pursuit of science and of knowledge in general is, I suppose, an idiosyncrasy exclusive to the genus Homo. Scientists are all men: they admit it and are, presumably, not altogether dissatisfied with their zoological status. However, in spite of the fact that science is of man, the direction of scientific endeavor seems to be mainly centrifugal or perhaps homofugal. I mean that the quantity of scientific interest in any phenomenon or in any conglomeration of matter seems to vary directly with its remoteness from man himself. Thus there are scores if not hundreds of scientists who are looking for new stars and investigating spiral nebulae, for every one who is studying anthropoid apes. Popular interest wallows in the eccentric wake of professional science. The Century of Progress Exposition was nightly illuminated by a ray from Arcturus in the pompous setting of the Court of the Sciences, amid the applause of gaping thousands; the obscure little tent among the side shows which housed the great anthropoid apes was illuminated by such of the sun's rays as could penetrate its canvas, and was patronized during my two visits only by myself and a few straggling urchins.

Again, while one may admire the concentration of biological interest upon algae, annelids and crustacea, he must deplore the neglect which falls to the lot of mammals, primates and man himself. The only quantitatively appreciable biological studies which have been directed upon man are those of medicine and surgery—and these are inspired not so much by scientific interest as by fear of death and disease. Even in anthropology (the shamelessly impractical investigation of man) the vast majority of workers direct their efforts toward the meticulous examination of what man produces by way of material culture or social organization rather than to the determination of what he is by virtue of being a primate. So we have archeologists who know all about man's pottery, man's weapons and man's implements, and nothing about man himself; ethnologists who are preoccupied with systems of kinship, terms of relationship and the dry bones of social organization, and who care not one whit for the living flesh and blood of the social being; linguists who are willing to let him who will make out the meaning of language, as long as they can study the grammar and the syntax. And, finally, I fear that we have physical anthropologists whose interest in man does not extend much beyond caliper measurements and statistical tables of means, standard deviations and probable errors, and who thereby commit grievous errors which are not probable but certain.

As a matter of fact, modern men living at a primitive or low level of culture —"savages"—have received a greater share of attention from anthropologists than have civilized men, although too often the sequence of cultural contact has been Christianization, exploitation, extermination and finally scientific investigation.

It is not my present task to urge the desirability of studying the biology of modern civilized man, pressing though

the need of such a study may be; it is rather my privilege to point out the special opportunities afforded to the student of evolution in the observation of biological phenomena among primitive peoples.

These special opportunities may be classified roughly in three categories, which are, to some extent, overlapping and interdependent. Under each of these categories there may be enumerated and discussed several factors which operate in various biological situations to affect or even to determine one or more of the following systems of primitive man's biology: morphology, physiology, pathology, psychology, sociology. Specifically, the three categories of factors which peculiarly affect the biology of primitive man and consequently illuminate certain obscure places in the evolutionary process are: (a) those which arise from the close relationship of primitive man to his physical environment, (b) those which arise from the geographical isolation of primitive groups, (c) those which arise from the supposed mental and physical retardation and the demonstrable cultural "lag" of modern savages. Clearly these categories are not mutually exclusive and some of the factors grouped under each might well be assigned to another. Our chief interest here is to call attention to biological phenomena in primitive man which seem to spring from these categories of causes or influences, whether or not the specific causative factors can be isolated in one of the three main categories recognized.

I have described the first group of factors which particularize the biology of primitive man as those which arise from close relationship to his physical environment. I suppose that no one will dispute the statement that primitive man lives closer to nature than our civilized *Homo insipiens*. It is incredible, for example, that we should find in primitive society hordes of savages squatting before some bare urban Mother Hubbard's cupboard, tightening their belts or their breech-clouts, while food is rotting in the neighboring fields and professors of agriculture are tinkering with the daily price of gold. The primitive agriculturalist raises what he eats and eats what he raises; he does not raise that which he can neither eat nor barter nor sell. The primitive pastoralist drinks the milk from his cows or lets the calves drink it or makes it into cheese and butter; he does not pour it out in spiteful libations upon concrete highroads. He does not, in short, behave like a civilized human being.

Granting, then, that savages are more or less what their name connotes, what are the biologic implications of their environmental symbiosis? The first of these is, I think, the untrammeled operation of natural selection. By this I mean that the individual savage survives for the most part through the hereditary toughness of his organism and through the ability of that organism to batten upon or "eat off" its environment, that is, barring accidents. The savage engages from birth in a single-handed battle against his environment, unabetted by synthetic substitutes for deficient mother's milk, without benefit of orange juice, spinach and pediatricians. He grows up, if at all, in full possession of his tonsils and his appendix. In brief, he is bereft of, or secure from, modern scientific medical attention. Consequently, the savage, in the structure of his organism and in its functioning, presents an object lesson in those physical and physiological variations which have survival value, and in those which are, at any rate, indifferent. Some of the material of this exemplification of natural selection will be discussed, if time permits, in the body of this paper.

Another factor which arises from the

peculiarly close relationship of primitive man to his environment is relative uniformity of physical adaptation. The biological effect of this factor can be illustrated best by the contrasting diversity which civilized man exhibits in this respect. In our society division of labor effects stringent occupational selection, which is, in part, physical. Thus a professional pianist will have an extraordinary muscular development of the fingers, wrists and forearms; a ten-day bicycle-racer, of the thighs and calves; a jockey must be undersized and light; traditionally a policeman is likely to have flat feet. A few years ago I undertook a physical survey of the criminals of ten states. This involved also the necessity of securing adequate samples of the civilian population of similar ethnic origin with which to compare the physical characteristics of the delinquents. It was found to be extremely difficult to round up for measurement a sufficient number of suitable subjects for inclusion in this civilian check sample. One of my energetic and ambitious young field workers managed to get permission to measure the firemen of Nashville, Tennessee, for comparison with criminals from that state. However, this check sample has proved rather unsatisfactory, principally because the firemen are extraordinarily fat. Whether this corpulence is an effect of sitting in the fire-houses all day playing checkers, or the natural result of selecting a body of men on the basis mainly of political affiliation, or what not, I am unable to say. At any rate, without laboring the point, it may be stated that the adult male population of urban residence in civilized countries is differentiated physically by occupation to such an extent as to render it quite impracticable to examine the physical characteristics of large groups without making careful allowance for the specializations which may be due to occupational composition.

On the other hand, savages are likely to show physical adaptations which are uniform in groups rather than diversified in individuals. If one of a group shows variations of the femur and tibia which may be attributed to walking with a bent-knee gait, the chances are that all or nearly all of the group will show in varying degree similar adaptations, because they all live in the same kind of country and their bodily habits are similar. Lack of occupational specialization does not bring about the multiplicity of individual variations and adaptations which are very baffling to the anatomist or physical anthropologist who is working over the skeletal parts of tame whites. This simplifies the problem immensely for the student of functional adaptation, since in any primitive group he is likely to be presented with a large range of similar variations which he can analyze and interpret and from which he can generalize with comparative safety. It provides him with adequate and representative samples of the same modifications. Any anonymous skeleton of a white derived from a dissecting room is likely, on the contrary, to present a combination of morphological variations apparently due to physiological causes, which are inexplicable without the knowledge of the occupation of the individual who manifested them. I have an articulated skeleton in my laboratory which shows such peculiarities of the thigh bones and certain other parts that I have vacillated between speculations as to whether the man in life was a tailor, a Turk or one of those Russian performers who do that peculiar squat-and-kick Cossack dance. Alas, these poor Yoricks! We did not know them well, or at all, and we can make very little of their remains.

Sir Arthur Keith relates that he examined the supposed mummy of the Pharaoh of the Exodus and identified him as the veritable Pharaoh who re-

peatedly "hardened his heart," since he showed clear signs of arterio-sclerosis. But even this exact pathological-historical correlation involves a slight difficulty, since the mummy in question was not recovered from the bottom of the Red Sea.

The uniformity of the organic regimen in savages permits us to make reasonably certain deductions as to the relationship between their diets, their habits and their physiques. The Eskimo, for example, presents an excellent opportunity for studying the effect upon the body of an almost complete subsistence upon fish and flesh—generally raw. Many of the American Indians lived principally upon maize; others depended largely upon buffalo meat, while still others had as their staple of diet salmon or manioc. Certain pastoral tribes of Africa confine themselves almost exclusively to milk, beef and blood; the milk of the camel is the main article of food among some desert nomads; many of the congested populations of Asia live principally upon rice. Of course it is by no means universally the case that primitive peoples have unvaried diets consisting of one or two staple foods. As a matter of fact, many if not most savages eat almost anything which is masticable and will serve to fill an aching void and provide a slight amount of nutrition. Even the latter consideration is frequently neglected in some substances which are devoured by peoples in impoverished environments.

It is hardly necessary to contrast with the local group uniformity in dietetic habits which prevails among primitive peoples, the extraordinary diversity of diets which civilized man can command and does utilize. Modern means of transportation and of refrigeration permit the individual not only to vary his diet to an almost unbelievable degree, but also to indulge in many gastronomic specializations according to his constitutional type, his prejudices and his pocketbook. This again makes the interpretation of the individual's biology difficult if not impossible, unless you know what he eats and how much he eats. Some years ago Professor E. L. Miloslavich devoted himself to a somewhat bizarre anthropometric research—that of measuring the length of the large intestine in various ethnic groups. He found that he was able to classify his material in three main categories: (1) persons with short colons (brachycolic, up to 160 cm), (2) those possessing colons of moderate length (orthocolic, 160 cm–175 cm), (3) those presenting long colons (dolichocolic, over 175 cm). Miloslavich established the fact that medium-gutted types were particularly characteristic of Central Europe (Croats, Slovenes, Czechs, Germans, German Austrians); short-gutted types were at a maximum among Magyars, Asiatic Turks, Asiatic Russians and West Poles; whereas the dolichocolic group included most of the Southeastern Europeans (Serbs, Montenegrins, Russians, Slovaks, Rumanians, European Turks, Ruthenians).

Our visceral investigator was cautious in drawing conclusions from his data, but he intimated that changes in environment may influence the length of the colon, just as head form changes in the children of immigrants born in this country. Thus European Turks tend to show Balkan rather than Anatolian types of colon, whereas East Prussians have apparently added a cubit or two to their colic length, by sojourning in the Slavic region. Possibly diet has something to do with these variations—a statement which brings me to the point of this illustration. It is well-nigh impossible to make correlations of diet with anatomy and physiology in civilized European peoples because of their promiscuous feeding habits. Thus we are left in an unhappy state of uncer-

tainty as regards the significance of our colic lengths; whether, if they are short, it is because we are or ought to be carnivorous; or if there are any vegetarian or frugivorous implications of dolichocoly. Contrast with this the pleasing certainty of deduction which attaches to recent and as yet unpublished researches of my friend, Professor George D. Williams, of Washington University, who has been soaking up the desiccated tissues of some Eskimo mummies from Greenland. Dr. Williams and his colleague, Dr. H. A. McCordock, have identified roentgenographically and histologically a large number of the calcified eggs of fish tape-worm in the liver of one of these defunct Eskimos. Now we know that raw fish is a staple of Eskimo diet. We need not worry about the individual tastes and habits of Eskimos—an Eskimo must eat fish and does eat fish, whether he likes it or not, and he eats it raw. Therefore the incidence of fish tape-worm among Eskimos does not depend upon the idiosyncrasies of individual Eskimos as much as upon the degree of tape-worm infestation of the fishes they eat. In other words, if we find a tape-worm in a civilized individual we can infer only that the person in question has eaten something from which he acquired a tape-worm; but if we find it in a savage, we may plausibly deduce that the same kind of unwelcome guests are probably running riot or living riotously in many of his fellow savages who subsist on precisely the same diet.

A second category of factors which contributes to the peculiar instructiveness of primitive biology is that which arises from the geographical isolation of savages. The first of these factors is the intensification of hereditary traits by inbreeding. This leads to clear demonstrations of genetic factors in the production of physical types and illuminates the causes of racial differentiation. It may be that it is isolation which keeps the savage savage, or it may be that the savage becomes isolated because he is a savage. In any event it is certain that only isolation keeps the savage alive, since he is almost invariably exterminated by contact with civilized peoples. I recently heard a highly educated Pueblo Indian girl comment with gentle irony upon the elaborate celebration of Thanksgiving Day forced upon the Indian children in the government schools of the Southwest. Certainly no savage has reason to be thankful for the invention and development of modern means of transportation or for anything else which has made him accessible to the lethal white. There is even some reason to doubt whether the bringing of all parts of the world close together has been an unmixed blessing to civilized nations. Facile communication is as likely to lead to trouble as to better understanding.

Be that as it may, civil communications corrupt good savages. Isolation means salvation for the savage, and for the biologist who studies him it means that his subjects are protected within the walls of a natural laboratory. Since the only areas which remain isolated today are those which are relatively unsuitable for the maintenance of the large populations of domesticated man, the savage generally has to live in environments which do not favor or permit a great increase in his numbers. Consequently, intensive inbreeding takes place. This effects the isolation of homozygous types. The combinations of recessive characters which result are often very unfavorable, but the persons possessing such combinations tend to be eliminated by natural selection, leaving the dominants purified of abnormalities, monstrosities and serious weaknesses. I have no interest here in arguing the relative merits of inbreeding and outbreeding in human stocks. It is my task

merely to point out that the rapid isolation of homozygous factors in man as a function of the intensity of inbreeding may best be observed among savages.

It seems probable that most of the hereditary physical characteristics which we utilize as criteria of racial types are either favorable variations which have a survival value or indifferent variations which are dominant, or variations which are alike beneficial and dominant. There is little or no chance of appraising the significance of racial variations or of other physical variations in the stew of hybridized populations living under artificial conditions of civilization. Here recessive weaknesses of hereditary origin are obscured by heterozygosity. They are overlaid by dominant traits to such an extent that probably the majority of us are little better than perambulating whited sepulchers. Recessive combinations of inferiorities are in part protected by a fatuous humanitarianism—immured in prisons, insane asylums, almshouses and other public institutions. But many of them stalk or hobble unrecognized through the civilized scene, playing every occupational rôle, but none of them well. Under these conditions genetic observations are well-nigh impossible, on account of the lack of pure lines, the presence of an infinite variety of mixed strains, the complexity of the environmental setting and the benevolent interference of science and social uplift with the operation of a purgative natural selection.

On the other hand, if the geneticist or the eugenist (and I do not mean by the latter a Nordic propagandist) is permitted to make his observations in a relatively homogeneous savage society, he can note the inheritance of features which appear to be racial and those which are suspected to be adaptive; he can judge to some extent whether characters are dominant or recessive, and can even hazard a guess as to the survival value of certain physical variations. If recessive features crop out he can observe the biological fate of those manifesting them, since among primitive peoples there are few if any obstacles interposed in the path of ruthless natural selection. If any physical variation is functionally advantageous, that advantage can be most readily discerned in groups which have not departed so far from the state of nature as to deprive the variation of its utility. If the woolly hair of the Negro has any survival value, that value must be determined by studies in tropical Africa, not in Harlem.

Yet another factor arising from the isolation of primitive groups and contributing to the profit of biological study of savage peoples is the range of environmental accommodations of the human organism which they present. Savages live, for the most part, in the remote places of the world. Wherever there is a place left for savages it is undesirable from the point of geographical location, climate or other detrimental features of the environment. The fever-infested swamps, the tropical jungles with their profusion of disagreeable flora and deadly fauna; the deserts with their poverty of nearly everything except sand and heat, the chilly inhospitality of the circumpolar regions—these are all the homes of primitive man. He has to get along in the regions which no civilized man cares to inhabit. Consequently, primitive peoples live under more diverse ecological conditions than the domesticated members of the human species and of necessity exhibit a wide range of physical and physiological adaptations. Civilized man prides himself upon adapting his environment to himself and it must be admitted that he has had no little success in this direction.

The clearing of forested areas for

agriculture, the irrigation of arid lands, draining of swamps and marshes, utilization of water power, destruction of insect and animal pests, are all methods whereby man utilizes or transforms his physical environment, thereby evading in large measure the necessity of adapting himself to that environment. Primitive or savage man has succeeded in ameliorating his environment to a very limited extent only. This is not necessarily because he is more stupid and less inventive than civilized man (although he may be both), but on account of the peculiarly unadaptable and recalcitrant environments to which he has been reduced. Although the savage may have "a goodly heritage," his lines have not "fallen in pleasant places." Practically all the inhabitable temperate zones and most of the endurable tropics have been wrested from him by his decidedly uncivil, though civilized, brother.

Under these circumstances the savage organism has to shift for itself in the most pestilential and dreary spots which the earth affords. Hence if you wish to find out how the human body accommodates itself to a continued existence generation after generation in tropical swamp lands, you must study certain savage tribes of the Amazon basin or of the Nile headwaters, or of other such undesirable places abandoned to the savage. If you are ambitious to discover the effect upon man of a sunless, steamy, tropical jungle, you may investigate the Negritos of Central Africa or of New Guinea. The influence of extremely high altitude upon the human animal can be ascertained among the relatively simple peoples of the Andes or of the Tibetan plateau.

Among the phenomena which arise from the geographical isolation of primitive groups is the stabilization of hybridized types. Race mixtures are most extensive in civilized society, but usually take place under conditions which make scientific observation very difficult and, frequently, impossible. In the first place miscegenation has gone on so long among civilized peoples that an almost infinite variety of mixed types already exists and pure racial types can not be isolated with any degree of certainty. The hereditary combinations have become so numerous as to defy genetic analysis. This is particularly true in the group of races which are crudely classified as "white." Dr. R. R. Marett has remarked that "a casual observer of savage life is apt to imagine it a welter of amatory confusion."[1] He might well have added that a scientific observer of civilized life is forced to regard it as a broth of mongrel promiscuity. Such a statement applies not only to mixtures between the white races in Europe and in the United States, but also to wider racial crosses between radically divergent stocks in most parts of Latin America and in many Asiatic countries.

It is not only the great diversity of racially blended types which makes the study of race mixture so difficult in civilized countries, but also the social stigma under which wide crosses take place. By a wide or radical cross, I mean an interbreeding of two physically divergent races, such as occurs when a North European mates with a Negro. Such mixtures have taken place wherever propinquity has permitted, but usually in a clandestine and surreptitious manner, because of the superior social and economic position of one of the stocks involved and the depressed status of the other. Consequently, the hybrid offspring of such marriages are socially rejected by the dominant and usually paternal race and are relegated to the subordinate stock which absorbs them by back-crossing. Thus there is little or no stabilization of hybrid types but only a small seepage of blood from

[1] R. R. Marett, "Faith, Hope and Charity in Primitive Religion," p. 77. New York, 1932.

the socially exalted race to that which is socially abased. In course of time such a continued dilution alters the complexion of the recipient race, but only gradually and almost imperceptibly. The great reservoir of so-called American Negroes has been considerably contaminated by this steady trickle of white blood, but not in such a way as to make for the stabilization of a new and relatively homogeneous racial type.

Such a state of genetic obfuscation is not usually brought about by the contact of races under conditions of primitive isolation. One reason for this is that primitive peoples are probably not race-conscious to the deplorable or laudable extent which is characteristic of civilized populations. I mean that they are rather naïvely free from race prejudice until they have learned it from bitter experience. The American Indian was quite ready to take the European literally to his arms until he found out that a civilized embrace was inevitably throttling. Racial crosses effected on a basis of social equality between whites and primitive races have occurred only in areas of isolation where white men have come without women and without the numerical superiority which enables them to assert their dominance and to enslave their savage hosts. Such conditions have been realized in a number of out-of-the-way places and have resulted in the stabilization of some new and biologically interesting hybridized types. Among the most important of these may be mentioned the Rehoboth hybrids of Southwest Africa, the result of marriages of the Dutch with the Hottentots; the inbred offspring of Tahitians and the English mutineers from the warship *Bounty*, on Pitcairn and Norfolk Islands; the Kisarese mestizos, descended from the mixture of a Dutch garrison with the natives of a lonely East Indian island. The study of these three groups by Fischer, Shapiro and Rodenwaldt, respectively, has contributed more to the knowledge of the inheritance of racial characters and the genesis of secondary racial types than could possibly be derived from the investigation of any racial mixtures taking place under the congested and infected conditions of civilization.

Another of the reasons why the stabilization of racially hybridized types is likely to occur among primitive peoples in areas of isolation is because sexual necessity knows no law, and islanders can not be choosers. In small primitive groups no maiden is allowed to wither on the virgin stalk, even if she has a touch of the whitewash-brush. A considerable increment of a new racial stock in an isolated primitive population is fairly certain to result in an amalgamation which transforms the entire group, because that group is small and the population inbreeds until the characters of both racial stocks are distributed about in a new and often homogeneous blend. There is no doubt that the Polynesian race originated thus from a tri-racial mixture of some sort of white or Caucasoid stock with Melanesian Negroid and Mongoloid elements. It is still possible to observe the process of race-making by hybridization in areas where primitive races meet and where the mixture subsequently stews in its own juices.

The last general category of special biological opportunities in the study of primitive man is that which arises from the supposed mental retardation and the demonstrable cultural lag of modern primitive men or savages. I am rather dubious as to the validity of this category, since no one has ever proved that savages are in reality mentally retarded or even inferior in intelligence to civilized peoples. Even if this supposed mental retardation exists in fact, it is difficult if not impossible to relate it to biological phenomena in any significant

fashion. Again, although there can be no doubt that savages are culturally backward, it is by no means clear that any causal relationship obtains between the inferiority of their material and non-material culture and certain archaic biological patterns which they preserve. On the whole, it seems the part of prudence to look this difficulty boldly in the face and pass on. For there are, at any rate, a number of vestigial biological features which still persist in savage society but have vanished in civilized communities. These are of enormous interest to the student of evolution. They include a number of certainly archaic morphological characters, some possibly primitive physiological processes and sundry variants of the modern biological family grouping. All these may be classified as survivals. Primitive morphological features, such as protrusive jaws, large teeth, undeveloped chins and small brains, probably owe their preservation in savage groups to a lack of competition with more advanced evolutionary variants. Such scanty genetic evidence as is available seems to indicate that more highly evolved physical characters tend to dominate over those which are less advanced. Thus Negro prognathism is rapidly diminished to the vanishing point in crosses with orthognathous white stocks.

Furthermore, in spite of the vigorous operation of natural selection in primitive society, social selection appears to be in abeyance, at least as far as social selection implies the preferential mating of individuals with highly evolved racial characteristics. Of course social classes and social stratification exist to some extent in savage society, but they are not necessarily, or usually, associated with physical differences, even when the group is racially of composite origin. Correlation of racial physical features with a superior social status seems to depend rather upon the subordination of a culturally primitive people by more advanced newcomers who are racially distinct and who both mingle with the aborigines and at the same time impose upon them their own esthetic ideals of racial beauty. This is a phenomenon typical of race mixture under the special conditions described.

However, in a simple savage group which is racially comparatively homogeneous archaic morphological features are likely to be distributed generally in the population and are not subjected to the Mendelian dominance of more highly evolved features brought in by a new race. Nor does any stigma of social inferiority adhere to prognathous jaws and black skins when every one possesses them. It follows that primitive ancestral traits, whether anatomical, physiological or sociological, flourish like the green bay tree in isolated savage societies, as long as they are not detrimental to the survival of the species. "If thine eyebrow offend thee, pluck it out" is a maxim which would not be current in an unspoiled primitive group whose racial features include a thick and continuous supraorbital fringe of hair. Man in a state of nature has never learned to despise those features of his physical inheritance which may be reminiscent of an ape ancestry, nor to exalt and select as eugenic ideals bodily traits which may be the end products of degenerative evolution. This idyllic catholicity of taste in bodily beauty is in happy contrast with the perverted fastidiousness in racial characters which has grown up in certain civilized peoples of mixed racial origins.

In Germany the obsession of race has grown from a morbid inferiority complex to a national psychosis. It so happens that the Germans have fallen into the unfortunate habit of taking their science in general, and their anthropology in particular, too seriously. A most important element of their historical

and political education is the conscious effort to build up in their citizens a physical ideal of the traditional German, tricked out in Nordic racial lineaments and replete with all the heroic virtues of a superman. Thus the official German is tall, broad-shouldered, lean-flanked and clean-limbed (whatever that may mean), dolichocephalic or long-headed, with yellow blond hair, eyes of cerulean blue, fair pink skin (such as one loves to touch), thin, high-bridged nose uncompromisingly straight in profile or with just a hint of the aquilinity that is aristocratic and not Semitic, thin determined lips, long horse face, and an aggressive chin.

Now this is all very attractive, but quite inaccurate. Comparatively few Germans answer this description. Undoubtedly a far more typical Teutonic portrait would be: short, squat, thick stubby limbs, protrusive abdomen, head flat at the back, bulging at the temples, brachycephalic; hair mousy brown, eyes mixed or beer-colored; skin muddy, nose bulbous, blobby; jowls pendant, lips blubbery, chin multiple. Several other descriptions different from either of the preceding would apply to great hordes of true Germans with sufficient exactitude. The facts of the matter are that the area of the present German Reich has been occupied since early Neolithic times—perhaps six thousand years ago—by three or four different racial stocks of the white division of mankind, and by a great variety of mixed types which have arisen from their interbreeding. At no time is there anthropological evidence that it was wholly populated by golden-haired Nordics, although doubtless this element was predominant in Northern Germany up to early historic times. The result of inculcating into the German people this spurious racial ideal of a supposititious Nordicism has been singularly unfortunate. First of all, it has promoted the development of a process of social and sexual selection which depreciates all racial combinations of physical features except one only. The latter certainly does not represent a crystallization of the sum total of racial virtues, whether physical, mental or moral.

This lusting after Nordicism has developed in the German people of non-Nordic physical features (and these include the vast majority) a racial inferiority complex which has vicious outlets in several directions. The most sinister activity emanating from this complex has been the persecution and expulsion of the one element in the German population which is generally agreed by Germans to be non-Nordic, or, of late "non-Aryan"—namely, the Jews. Apart from this unfortunate people every German is his own Nordic and is allowed to explain his deviation from the official racial type in a variety of more or less plausible ways. Most of these have been invented by patriotic German anthropologists, who have been forced to the most astounding subterfuges in their attempts to derive the modern brunet, brachycephal Germans from the traditional blond long-heads.

One of these was the famous but rather unconvincing effort of the Bavarian anthropologist, Ranke, to prove that the Bavarians owed their round-headedness and their dark complexions to a prolonged sojourn in the Alpine foothills. Another ingenious idea related the brachycephalization of the modern Germans to an increase in cranial capacity or brain size. Since a spherical container is the most economical in form, it is quite evident that an accretion of brain mass would tend to transform an egg-shaped skull into one broader relative to its length, if such an increase were accompanied by no general enlargement in body size. However, a slight difficulty in the way of accepting this explanation is the fact

that no increase in cranial capacity or in brain size from prehistoric to modern times has been demonstrated in the German population. One of the most amusing efforts to prove that the German people are blond was the pigmentation survey of six million school children carried out by the Government soon after the Franco-Prussian war. It is well known that in mixed races containing blond and brunet strains, light hair and eyes manifest themselves temporarily in infancy and childhood, but a subsequent addition of pigment causes darkening of hair and eyes in adolescent and adult life. Neither infantile nor Hollywood blondes can be accepted as unquestionable Nordics.

None of these expedients have succeeded in convincing the Germans themselves, or any one else, that they are predominantly Nordic in their racial characteristics. Hence they wreak their inferiority complex upon the Jews, and still the inward clamor of their doubts by waving swastikas and by pulling the beards of ancient Israelites (who probably possess as much Nordic blood as they themselves). This lengthy digression into modern biology is not justified by my subject, except in so far as it emphasizes my point that savage societies offer superior advantages for the observation of racial characters and especially for studying archaic morphological patterns, because in contrast to civilized man the savage is naked and unashamed. And if I have trespassed upon the preserves of the following speaker, I can only plead in extenuation the wilful nomadism of the physical anthropologist, who insists upon a range of investigation all the way from the higher primates to the lower politicians.

I have listed among the special opportunities offered to the biologist in the study of primitive human groups the preservation of physiological processes which are also primitive. In an expansion of this paper I intend to justify this claim to an extent limited by the exiguous amount of physiological research which has been carried on among savages. Frankly it is in large measure an assumption, based upon the indubitable fact that archaic morphological patterns are preserved among savages and upon the rather questionable inference of a parallelism between form and function. I take it that the strongest evidence in favor of a primitive type of physiology among savage peoples is found in the higher percentages of such remote groups which exhibit, apparently, the lack of the blood group agglutinogens, A and B, which occur as dominant mutations and have been diffused throughout the more civilized peoples. The vague and uncertain indications among savages of a partial retention of the sexual periodicity which may have characterized our protohuman ancestors are hardly worth a passing mention, since it is now known that apes and monkeys, like man, make love all the year round. Such indications are probably illusory. But the studies of the relation of sex and the reproductive cycle to the social life of baboons, recently carried out by Dr. S. Zuckerman,[2] point clearly the importance of these factors in the social organization of primitive man. The physiology of reproduction, if it does in fact condition the entire social life of man, may best be studied in the simpler savage groups.

The indubitable survival in savage society of primitive variants of the biological family grouping offers a field for research which still retains many fruitful possibilities for the social anthropologist and for the physiologist. In the minds of most civilized peoples there appears to appertain to monogamy a certain moral sanction not dissimilar to that adhering to the conception of mo-

[2] S. Zuckerman, "The Social Life of Monkeys and Apes." New York, 1932.

notheism. Both are considered to be now as they were in the beginning and ever shall be, world without end. Somewhat more liberal treatment is accorded to man than to the deity, in that the former is allowed to have, at any rate, one wife. This monorail type of belief and practise does not obtain in all primitive societies. If there has been any sort of evolution of the family in man, its stages can be reconstructed only from the investigation of the higher primates and of primitive man, although the disruption of that grand old institution is abundantly exemplified in civilized society. Whether or not these familial variants in savage groups arise from mental retardation or cultural lag is a question I propose to argue subsequently.

So far you have been treated to an effusion or spattering of reasons why primitive man makes the ideal laboratory animal, supported largely by contra-indications with respect to civilized man. I do not wish to give the impression of a mere sadist flagellating civilized man over the shoulders of the savage. The foregoing pages are, rather, in the nature of a preambulatory survey —a sort of preliminary scientific sniff. The opportunities of savage biology should be discussed under the several headings of morphology, physiology, pathology, psychology and sociology. Obviously none of these subjects can be exhausted within the limits of the present paper. It is possible only to exhaust the listener and the allotted time. This much already has been accomplished. I must beg the pardon of my audience for proceeding directly from grace before meat to finger-bowls. If you have been offered nothing more substantial than a menu-card, you are spared, at least, the pangs of indigestion.

MODERN SOCIAL ORGANIZATION

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THE essential traits of modern social institutions derive from the emergence of a free society out of the caste society of the feudal epoch. The most important contrast between the two social orders is in the extent of free mobility, or the opportunity of the individual of superior gifts to elevate his social status and likelihood that one of inferior capacities will, of his own weight, sink in the social scale.

The development of democratic individualism destroyed more or less completely, especially in the newer parts of the western world, the medieval class alignment of aristocracy, clergy, tradesmen, artisans, freeholders and serfs. That was in many respects a society of hereditary classes, in which all but a few individuals remained in the social status into which they were born. There was, no doubt, some mobility or movement from social level to social level. Strong and able men pushed upward from low to high ranks. They did so, however, by the force of their own personalities and against both tradition and social opposition. Such mobility increased with the growth of the towns as the middle classes of merchants and traders grew in numbers and importance, especially after the commercial revolution. In general, however, that society tended to preserve the biological composition of the different social classes in a fairly stable state. The slight mobility which it permitted may warrant the assumption that on the whole the upper classes were by nature slightly more able and gifted than the lower. But such differ-

ences, if any, must have been slight in such populations as those of Europe, where the superposition of race and class was largely a consequence of historical chance and change and, so far as we know, no indication of biological differentiation.

Another important feature of medieval society was the very definite and effective restriction on marriage of the lower orders. The somewhat scanty data available show that while the upper, independent classes married earlier than at present, the lower classes not only married considerably later but often did not marry at all. Restrictions were imposed by custom and law, as well as by the force of a stationary or slowly improving economic situation. Broadly speaking, serfs, cotters and other cultivators of the soil could not marry until a house was made available by death. Pollard notes that during the middle ages "the number of holdings was almost stationary and the number of families fixed."[1] In the towns, guild regulations not only bound apprentices for a long term of years but made difficult the marriage of journeymen. As the guild system reached its height its regulations and requirements for membership became more strict. One of the objects of these regulations was to prevent early marriage.[2] In addition to a considerable number of celibate servants and servitors, there was a large number of religious celibates, drawn mainly from the lower classes.

The emergence of middle-class democracy, reinforced by the transforming power of the industrial revolution, fundamentally altered both these outstanding traits of medieval society. It raised social mobility to the highest pitch and made early marriage the privilege of the lower classes and late marriage almost a necessity of the upper. Democratic society sought the obliteration of class lines and did succeed in destroying most of the remnants of hereditary title and privilege. It sought to establish equal opportunity for all. It asserted its devotion to the doctrine of "the open road for talent." It prided itself on establishing a social order in which men would be rewarded according to their individual merit regardless of their birth and in which positions of power and responsibility would be attained by those who proved their worth in fair competition with their fellows. Its ideal was to give all as nearly as possible an equal start in life and by removing handicaps to enable the best man to win. To these ends it established the system of universal, and even compulsory education, often with scholarships and other aids for the poor but worthy, in order to enable the individual to rise as high as his ability, energy and perseverance would carry him. Democracy was animated by the belief that the main causes of differences in social status lay in differences in the start in life or in environmental circumstances. Men were believed to be by nature equal or nearly equal, so that, if the socially handicapped were only educated and prepared for the competitive struggle of mature life, we should destroy poverty, equalize wealth and spread the benefits of our higher culture more or less evenly through the entire population. This is still a living faith among large elements of the American people.

However, a century of extensive experiment with these ideas leaves us with a society more or less definitely stratified as regards wealth, power and culture. The class differences in most of the objective marks of class seem to be as great or nearly as great as formerly. In actual amounts of property and income they may be even greater. The growth of a complex civilization is accompanied by the process which the sociologist calls

[1] Quoted by Carr-Saunders. "The Population Problem," 280.

[2] *Ibid.*, 281.

pyramiding, or a tendency toward an increasing division of labor, a finer and finer occupational stratification of the population and an increasing difference in the wealth and power of those at the top and those at the bottom of the social structure. While we have had a society in which mobility has been raised to the highest possible level, most of this mobility is lateral, or the movement of men from place to place, or from occupation to occupation, without much change in social rank. We tend to re-form into a caste society while maintaining the outward forms of free mobility. The upward movement of the able, energetic and ambitious has been facilitated as a conscious social policy, while at the same time it would seem to be increasingly true that each class recruits itself mainly from itself. The thesis I present then is that our democratic individualism destroyed a society based on hereditary title and privilege but with considerable biological homogeneity among the classes, and with definite restriction of the fertility of those least able to support offspring, only to produce a society having little hereditary privilege but in which biological differentiation between the social classes has become more and more marked, and in which the fertility of those most fitted by birth and resources to produce offspring has been widely restricted.

All features of our culture have cooperated to produce this new stratification. In the first place, the unparalleled material progress has given a tremendous and long-continued stimulus to ambition. The prizes of life have been very great, and the fields in which they have been offered have been numerous, varied and inviting to men of talent and ambition. During much of the last century new lands and vast new natural resources were being opened up for exploitation. The progress of science and invention created ever new opportunities, as did also the steady improvement and exploitation of capitalist, industrial techniques. All this was accompanied by a rapid increase of population, which, together with a rapidly complicating culture, furnished a continuously expanding arena for the ambitious. There always seemed to be room at the top and sure rewards for those who combined energy, ability and persistent effort.

Then, in the second place, the régime of free competition made these prizes available for all and sundry, regardless of birth. We held these prizes steadily before the eyes of ambitious youth and sought by education, precept and example to stimulate them to their highest efforts. The popular mind was repeatedly thrilled with the stories of men rising from poverty to affluence or from unfavorable social environments to positions of power and honor.

In the third place, universal popular education undoubtedly succeeded in accomplishing to a large extent its conscious purpose of lifting the poor and obscure individual of sound mind and body to a social level corresponding more or less accurately to his capabilities. A century ago those who went to college came almost exclusively from families of considerable culture and nearly all of them expected to enter the professions. With the improvement and extension of educational facilities the backgrounds of high-school and college students became more diverse, until, during recent decades, the colleges have drawn boys and girls of all racial, national and occupational groups. Our educational machinery has thus become, in fact, a gigantic sorting apparatus.[3] All children are taken in at the bottom and a very considerable proportion of them are carried as far as

[3] N. J. Lennes, "Whither Democracy? Does Equalizing Opportunity Create Hereditary Social Classes?" Harper and Brothers, 1927.

their ability, temperament and ambition will permit. So far as education is synonymous with opportunity in our culture, millions have had more of it than they could utilize.

No doubt it is true that the educational machine has not been perfect as a selective device. Some children have been compelled to drop out because of poverty or some unfavorable life contingency. The gradual extension of child labor legislation and the progressive elevation of the ages of compulsory education have, however, sought to prevent children leaving school before the ages 14 to 16. They have reduced the exploitation of children by parents, and in doing so have probably become important factors in the reduction of the birth rate. They have, however, gone far to enable talented children to be discovered or to discover themselves, so that with the increasing provision of scholarship and other aids, gifted boys and girls have been able to rise from the lowest levels to the highest. Moreover, the most extensive researches thus far made indicate that the most frequent cause of elimination from the grades below the high school is retardation because of low mentality.[4] There is an extensive body of testimony as to the general association between brightness and progress through the schools. A fundamental principle which has exerted enormous selective influence through the educational system is that bright children not only learn faster than dull ones but they continue to learn longer. Bright children in general have taken greater interest in educational activities. They have been more readily stimulated; their ambition more easily aroused. The extensive development of higher education, both cultural and vocational, has been accompanied by extensive recruiting of the bright and able from all social ranks. There is much evidence that those who have succeeded well at any given point in the educational scheme have been generally selected for still more education. There is a gradual elevation of the average IQ level from grade to grade. Those entering the high school from the grades excel those who finish the grades but do not go on. So also with reference to those who graduate from the high school and go on to college or special training. Moreover, it has become increasingly true that access to the higher vocational levels has become increasingly dependent on success in passing through the educational machine.

I would not exaggerate the extent of this selection of intelligence. The evidence, such as it is, indicates that a smaller and smaller proportion of those who are mentally capable of doing the work reach each successive grade after the fourth or sixth. If, however, of those having the requisite ability only one half complete the high school and not over one fifth the college, and if a proportion of these are thereby drawn to higher social levels, the upshot of these conditions would be the maintenance of the biological quality of the upper levels by recruits from below. This process would lead inevitably to the relative genetic impoverishment of the lower classes. Unless the genetic principles governing man's traits are essentially different from those of his domestic animals, one may be quite certain that the selective processes above sketched, even if they acted only roughly, would in two generations result in measurable differences in the distribution of the selected traits in the upper and the lower levels of our population.

One may hold that selection has not worked; or he may hold that, even allowing for some selective mobility, the population is an inexhaustible reservoir

[4] E. L. Thorndike (1907), Leonard P. Ayres (1909), Helen I. Wooley (1923), L. Thomas Hopkins (1924), and others.

of gifted and able strains; or he may argue with the social environmentalist that elevation in the social scale is a consequence of favoring circumstances and has little or nothing to do with heredity. None of these positions appears tenable in the light of facts. No doubt there are social advantages and disadvantages distinguishing different elements in the population which tend to perpetuate themselves under the operation of sentiment, law and economic forces. Nevertheless, the differences between our social stratification and that of a hereditary class society seem to be so great as to make any analogy between the two fundamentally erroneous.

It is particularly argued that bad environments have cumulative effects. The poor are poor because their parents were poor. So also with the ignorant, the wayward and the vicious. No doubt there is some truth here. The standard of living in any family strain tends to perpetuate itself. A low standard, for example, is associated with early marriage, with inadequate preparation for economic success and with too numerous progeny. This round of events tends to repeat itself. At the opposite end of the social scale the opposite round of events likewise is repeated. Moreover, it is probably easier to prevent an ordinary person born in high status from sinking in the scale than it is for a somewhat more gifted person to rise.

However, there are certain countervailing considerations. Over against cumulative and continuing effects of a cultural environment may be set both the direct and the indirect effects of heredity. In the American environment opportunity has most of the time been not inconsiderable; education has been nearly universal; and the stimuli to advancement have been numerous. If under these conditions a family remains steadily from generation to generation on very low levels of social efficiency, one may at least suspect that heredity is an important factor in the situation. Conversely, if a family maintains itself from generation to generation on a high social level, amidst the changes and chances of a complex culture, with the necessity of constant readjustment to a changing social milieu, one may suppose that good stock is represented. Heredity in the long run and to some extent either shapes or finds its own environmental level. It is not an accident that investigation after investigation, using different criteria, finds the better stocks in the better environments and the poorer stocks in the worse. Able, energetic parents, taken as a group, not only tend to produce able and energetic children, but they provide for them healthful surroundings and good education. Stupid, unstable or lazy parents tend to have children like themselves and to rear them in less than optimum environments. In a freely competitive social order the environmental status of a family may very plausibly be viewed as to some degree a consequence of its special combination of genetic traits.

Then there is the obvious fact that many thousands have risen and are rising from lower to higher levels, while others are sinking in the social scale. Sheer luck is no doubt a factor here. Nevertheless, by every test we have, whether mental test, educational success or achievement in practical affairs, those that ascend are, on the average, more able than those they leave behind. Certainly, one of the greatest ambitions of average American parents has been for their children to rise to levels of higher social esteem. Manual workers by the millions have striven to give their children every opportunity to move into the soft-hand, white-collar vocations. Finally, we may observe that unless this upward mobility has occurred, then our

vast expenditures for education have been a hideous deceit. If, in spite of our elaborate educational machinery and the multiplication of social service activities, it is still possible to say that those who have been most successful in solving the problems of life in our society are inherently no better than those who have been least successful, then democracy has utterly deceived itself.

Such *a priori* arguments as the foregoing for the natural superiority of the upper levels are strong enough in themselves to convince many, but the skeptical scientist will seek more direct evidence. In the first place, we need some objective marks whereby social levels may be differentiated. For this purpose we may utilize occupation, as in the Army or the Barr scales, or the conventional grouping into professional, business, commercial, skilled and unskilled groups. We may use the amount of education, such as completion of certain grades, high school, college, technical school, university, or professional school. We may use also income, home rating scales, social status scales, and similar devices. All these measures tend to correlate highly one with another. Moreover, they represent the popular and widely approved estimates of social status. Our schemes of education and of economic promotion are designed to lift individuals upward from one such level to another.

If, now, we raise the question whether these levels represent a biological gradation we are confronted with the difficulty of finding satisfactory marks of biological worth. For this purpose it is obvious that no external physical marks, such as hair color or shape of nose, will do. A man's biological fitness for achievement in our complex society can not be judged by his stature nor by the size of his head, even though it be demonstrated that both of these traits tend to correlate slightly with our scheme of social levels. We can not be satisfied merely to say that those who have succeeded best have thereby proven their superiority, because it can be replied that success or failure are often due to good or bad luck, or to a favorable or unfavorable start in life.

The fact is that it takes a combination of qualities to succeed in the free-for-all competitive struggle of modern society. Vigorous health, energy, ambition, perseverance and intelligence are all involved. There is not a little indication that these traits tend to be found associated in the same individuals, but the intensity of the association is as yet far from clear. Terman's mentally superior children proved to be superior also in conscientiousness, perseverance, leadership, sense of humor, physical development, energy and general health. Thorndike says "Intrinsically good traits have also good correlatives."[5] Various studies reveal a greater frequency of physical defects among the mentally retarded than among the normal. The study of the association of traits is a promising field of further research.

The only trait upon which a large amount of evidence is available is intelligence. This is measured by mental tests and by progress through the educational machine. These two measures are highly correlated. They are also found to be useful practical measures and to correlate highly with actual success in the competitive struggle. They correlate highly with any scheme of social levels. However, in spite of twenty years' intensive investigation during which tests and testing technique have been greatly improved and during which the general picture of social stratification revealed by the earlier tests has remained substantially unaltered, there are still many who doubt the value of these measures as measures

[5] "Educational Psychology," III, 408.

of innate ability. To them we may observe that innate intelligence can not in any case be measured directly. It can only be measured by what it does. If we allow for a certain roughness in approximation, we seem bound to say that children who do well the things an intelligent person in our society is expected to do may reasonably be supposed to have more intelligence than those of the same race and community who bungle the same tasks. It must be admitted that mental tests are not a thoroughly satisfactory measure of inherent ability; their results are too much affected by education and training for that. We freely admit their weaknesses, while claiming they are the best measures we yet have. In a later section we revert to the extent to which the IQ level may be supposed ordinarily to be raised by average educational advantages.

If, then, for the sake of the argument at this point we take intelligence tests and scholastic records as roughly indicative of ranking in terms of innate intelligence, we note the correlation of social level with IQ level has been so fully demonstrated by repeated research that it needs no detailed proof here. Mental scales of occupational ratings are in extensive use both in research and in practical vocational placement bureaus.

We may now advance the thesis one more step by noting that marriage occurs for the most part among persons of the same social level. In general people marry within their own status group, according to such measures as cultural and educational attainments, occupational similarity and residential propinquity. These are indirect and very unprecise indices of biological similarity. When the extent of assortative mating is measured more directly, there are found to be sensible correlations between husband and wife for stature, certain other bodily traits, complexion traits, longevity, general health, parental fertility, insanity, tubercular infection, criminality, alcoholism, congenital deafness, feeblemindedness and mental deficiency, intelligence and various temperamental and character traits. This is, on its face, an imposing list, though obviously much mixed as indices of genetic similarity.

The highest consistent correlation is found for intelligence, that being twice as high as for physical traits (stature, fore arm, span, hair color, eye color, longevity and general health) which run from 20 to 30 per cent. On the whole, the conclusion seems warranted that there is a measurable tendency toward the mating of persons of similar mental level. It seems probable that this tendency is more marked on the lower and on the higher social levels than through the middle registers. Lidbetter has shown it to be very marked among the social problem group of London, and this harmonizes with the indications of numerous family history studies of "ne'er do weels" in this country. For the business and professional classes equally convincing evidence is lacking, and the tendency may well be less pronounced. However, it is on the higher levels that mental qualities seem to play the larger rôle in mate selection, for along with them go similarities of taste and enjoyments, sympathy and mutual understanding. As Holmes says: "Mediocrity tends to mate with mediocrity and superior types tend to select their mates among the superior."[6]

Thus far we have argued that the social organization of the past century has favored the upward mobility of the more able and energetic individuals, thus bringing about a tendency toward biological stratification of the population; and that the phenomenon of assortative mating further tends to fix and maintain this stratification. Moreover, it is

[6] S. J. Holmes, "The Trend of the Race," p. 231. Harcourt, Brace and Company, 1921.

implied that this stratification has occurred most clearly with respect to innate mental capacities. The demonstration is far from cogent, however, owing to the present uncertainty as to the relative rôles of heredity and environment in determining either mental level, or any mark of social status.

It would seem, however, that the vast accumulation of research during the past generation supports the generalization that there is a direct relation between success in the modern social order and inherent ability. The very best of educational and social environments can do little for the slow and dull. Those who are dull in childhood tend to remain so, almost without exception, while those who are bright remain bright. We have talked much of equalization of opportunity, and have been inclined to forget that what is opportunity for the dull is not so for the bright and *vice versa*. In reality opportunity must be proportioned to ability. Indeed, the able and energetic find opportunity for self-development where the dull can only vegetate.

Professor Jennings and others have very correctly called attention to the fact that every trait is the result of the co-action of both heredity and environment; and they have cited instances, especially on the subhuman levels, of quite different traits developing from the same genetic basis under the influence of different environments. This has given rise to a wide-spread belief in a more or less indefinite organic plasticity. This view, that the organism is molded by its environment, has been especially welcomed by educators, social workers, a certain group of anthropologists and most sociologists.

Over against such a view it seems more in harmony with the facts to set the doctrine of organic responsiveness. Instead of holding that the environment shapes the organism to its own patterns, it is more accurate to state that the environment can call forth only such responses as the organism is qualified by its genetic constitution to make. No trait for which the genes are wanting can appear, regardless of the environment. Moreover, the correlation between the environmental stimulus and the associated trait is determined solely by the genetic make-up of the organism. Just as the Nordic skin, unlike that of the Negro, will burn but not tan, so the moron, unlike the gifted child, remains a dullard amidst the most perfect environmental stimuli. Millions of American children are subject to musical training, but relatively few reveal musical talent. And what is true of musical ability is true of a long list of capabilities, ranging from the handling of mathematics and abstract ideas to the muscular coordinations required in the manual arts. If it were anywhere near true that brilliant men and women could be produced by education we should now have millions of them.

This is not to say that good environment is not necessary; it is an obvious necessity. At the same time, when one sets himself the task of accounting for such differences as occur among the children growing up in an average American community, he need not forget that their environments ordinarily vary through only a small part of the whole range of possible variations. Nevertheless, from such a community will come individuals with most varied capabilities. The human product may vary 100 or more in IQ, even though the environment is relatively uniform. Moreover, it is an obvious fact that improved environment becomes more important in mental development as the hereditary potentialities become greater. One can state without fear of contradiction that equalization of educational environments will increase the range of individual variations, provided such equalization is in the direction of a gen-

eral improvement of educational facilities.

That mental levels tend to be inherited is supported by the general superiority of children of superior parents and the general inferiority of those of inferior parents. Not long since Professor Raymond Pearl[7] made a very curious attack on the Galtonian theory that superiors tend to breed superiors by attempting to show that 588 of the world's greatest philosophers, poets and scientists had sprung indifferently and according to the laws of chance from all levels of the population. Their fathers were said to be "an average lot of human beings." When, however, these fathers were graded according to the Barr scale of mental rank of occupations, they were found to rank above 93 per cent. of a random sample of the American population.[8] About 70 per cent. of the fathers belonged to the two upper classes in Taussig's hierarchy of occupations and none to the lowest. Pearl's cases were, in fact, strictly comparable to those of Galton, Ellis, Cattell and others, and also to Terman's group of gifted children. The product at the opposite end of the scale is too well known to need citation.

In view of the recent researches on heredity and environment in relation to twin and orphan differences, we can carry the argument to a somewhat more precise conclusion. These make possible a preliminary estimate of the influence of different heredities in determining mental level when environmental conditions are similar, and of the influence of different environments when heredity is similar. This evidence can not be adequately summarized here.[9] The following array of conclusions, each of which seems supported by adequate evidence, suggests that the IQ level is, by and large, little affected by such environmental differences as commonly occur in American communities. The mental resemblance between random pairs of unrelated children of a community is around zero; that between sibling pairs is around 50 per cent.; that between fraternal twins is about 60 per cent.; that between identical twins is much larger, ranging from 80 to 90 per cent.; for the siblings and twins the mental resemblance is somewhat higher than that for physical traits, measured by height, weight, respiration and pulse rates, but is nevertheless of much the same numerical order; there are slight changes, if any, in the degree of mental resemblance between twins as they grow older, though their continuance in the same schools and homes ought to make older twins more alike than younger; there is almost the same degree of resemblance between twin pairs in those traits believed to be little influenced by training and those believed to be much influenced thereby. Research to date indicates that the IQ differences between identical twins reared together average roughly about 5 points, or about the same difference as that between two closely consecutive measurements of the same individual. Ten pairs of identical twins reared apart were found by Newman and others to differ, on the average, by about 8 points of IQ, while non-identical twins reared together are found to differ, on the average, by about 10 IQ points and siblings reared apart appear to differ little more than those reared together. In all cases the range of variation is, of course, much greater than the foregoing average differences. Moreover, different schools of opinion put different interpretations on all such data. On the whole, the mass of the evidence seems to me to support the view that heredity is an important fac-

[7] "The Biological Basis of Superiority," *American Mercury*, 12: 257–266, 1927.

[8] D. G. Paterson and E. G. Williamson, "Raymond Pearl and the Doctrine that 'Like Produces Like,'" *American Naturalist*, 63: 265–273, 1929.

[9] For a most excellent summary, see Gladys Schwesinger, "Heredity and Environment," The Macmillan Company, 1933.

tor, if not the most important factor, in accounting for the differences in mental level among persons living under somewhat similar cultural conditions.

We may conclude this very inadequate summary of the evidence relating to mental level by expressing agreement with the finding of Barbara Burks that "the total effect of environmental factors on standard deviation up and down the scale is only six points." That is, about two thirds of the variations in IQ level due to such differences in home, education and other social influences commonly found in American communities do not exceed six points. In extreme cases such influences may account for as much as 20 or even 27 points. Heredity, on the other hand, obviously accounts for more than 100 points of variation.

The evidence thus pointing to an increasing biological stratification of the population is extensive. Our thesis is not designed in any way to validate the iniquities and imbecilities of the present social order. Nor is it a criticism of education, social work and other humanitarian activities. These rest securely on grounds of social necessity and benefit. Only those who pray for a dictatorship of the proletariat, presumably under their own benign guidance, need take exception. Its practical implication is the desirability of giving some attention to the respective fertilities of different social levels in a society that strives to maintain an open road for talent and at the same time suspends the operation of natural selection among the less capable. The biological resources of the population are not inexhaustible.

No doubt there are still considerable amounts of uncultivated talent in our midst. At the same time, I am inclined to think that the rapid progress of the last century is due in part to the successful exploitation of an unusual proportion of the latent abilities of the population. Talent has been found, stimulated to high endeavor and induced to work at high pressure under the shibboleths of achievement and efficiency. Then we have proceeded to sterilize an increasing percentage of the ablest and placed others of them under social conditions where their offspring have been too few to replace themselves. There has been a constant necessity of replenishing the deficit of the upper levels by masses of recruits from below. Galton advanced the opinion that the Inquisition was a factor in prolonging medievalism in Spain; and many have seen in the slaughter of the Russian intelligentsia and the recent expatriation of German scholars serious blows to the higher cultural activities of those countries. Far greater, in the long run, is the loss to this country because of the thousands who every year fail to be born among those, who by every mark of hereditary fitness and social superiority, are qualified to produce the natural aristocracy of the future.

EARTHQUAKES IN CALIFORNIA

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EARLY in the morning of April 18, 1906, one of the greatest fires in the history of the world broke out in San Francisco. It burned more than four days before it was brought under control. Unusual features were associated with it—streets were fissured, buckled, bent into wavy surfaces, and, where built on made land along tidal estuaries, warped laterally several feet down stream. Water mains outside the city were collapsed and buildings far from the area swept by fire were cracked, broken and tumbled down. In short, even the most loyal San Franciscans were constrained to admit that the outbreak of fire had been preceded by "a little shake," as I heard one man euphemistically describe it. Hardly had the fire ended when news came of a great crack in the earth southwest of the city—at first a vague, almost incredible rumor, but soon definitely and in authentic form—a long, straight surface fissure, or narrow belt of fissures, running southeastwardly for miles on end. Thus came dramatically to notice the surface trace of the San Andreas fault, broken anew in 1906. This fresh break at the surface was found to extend from the vicinity of San Juan Bautista in Monterey County northwestward for at least 180 miles, more likely for 300 miles or more, dying out probably under the sea—running past the Golden Gate under the ocean from Mussel Rock south of San Francisco to Bolinas Lagoon northwest of it. In the city it is still popular to call this event the "fire"—but the world knows that Central California then experienced an earthquake of major rank—though many greater shocks have occurred elsewhere. We know also that the immediate source of the destructive shaking was the San Andreas fault, along which for many scores of miles sidelong slipping of the adjacent crust blocks extended downward to depths measured in miles. The maximum horizontal offset was about twenty-one feet, near Point Reyes Station northwest of San Francisco.

Study of this earthquake could not fail to suggest close relationships between the many earthquakes on record in the annals of California and the numerous geologic faults of recent development which traverse and bound its mountains. Nevertheless, any attempt to fix the sources of particular shocks upon particular faults bristles with difficulty, for the shocks chronicled commonly were felt over extended areas and their descriptions usually lack adequate details. Also the faults are numerous and in many places closely spaced. Efforts to this end made it clear that intensive study of the occurrence of earthquakes in this province, with the close location of shock sources and their relation to the geologic structure, would yield results of importance at once to science and to public welfare. Such work in seismological research, conducted by this institution—in cooperation with numerous agencies, among which the California Institute of Technology, the U. S. Geological Survey and the U. S. Coast and Geodetic Survey are outstanding—is an outcome of the investigations set in motion by the earthquake of 1906. This is a small but important benefit to balance against the disastrous consequences of this shock.

The first problem confronted in this program of the intensive investigation of

COLLAPSE OF NORTHWEST CORNER OF SAN MARCOS BUILDING

A BUSINESS AND OFFICE STRUCTURE IN SANTA BARBARA, CALIFORNIA: SHOCK OF JUNE 29, 1925. AN EXAMPLE OF REINFORCED CONCRETE CONSTRUCTION OF INDIFFERENT QUALITY—BADLY DESIGNED TO RESIST EARTHQUAKE ACTION.

local earthquakes in a restricted province, subject to frequent shaking, was the development of instruments and instrumental assemblies suitable for such special purposes. Use could have been made of instruments already developed for the study of shocks of distant origin, but only under severe limitations. The need for registering in excellent fashion the large numbers of shocks too small to be sensibly perceptible was clear because, since such earthquakes usually affect small areas only, their causal association with particular faults would be easier to fix without ambiguity; and, on account of their numbers, any marked tendency for them to cluster along particular faults or in special areas should prove significant. Consequently, sensitive instruments are required which magnify rapid vibration greatly.

For mechanical registration very large masses would be necessary, which would introduce inertia and bending moments, as well as friction, in very undesirable ways. Optical-photographic recording, which permits the use of instruments of small dimensions and mass, became clearly indicated. The torsion seismometer provided an early and satisfactory solution for recording the

horizontal components of vibratory earth-motion. The vertical component proved less easy to deal with. It was finally found desirable to develop an instrument with galvanometric-optical recording to register this component of the earth motion. Once developed, a similar instrument, having the same characteristics and constants, is found practicable for registering the horizontal components. For very thorough study of the earth motion instruments of still different characteristics have been found useful and important because of the different emphasis placed by their written records upon different aspects of the earth motion. Auxiliary apparatus of this nature has yielded very interesting and important information.

The speeds of propagation of seismic waves are high. With local earthquakes, for which the distances between the origins and the recording stations are comparatively small, relatively large errors are introduced unless the determinations of time—the times of arrival of wave-phases, for example—are very accurate. When such phases are registered sharply it is desirable to determine their times to a tenth of a second or better. This is difficult to accomplish. It requires very uniform rotation of the recording drums at a rate somewhat faster than that commonly in use in the past. For economic reasons, since the recording must be continuous day in and day out, a very fast rate is impracticable. After much development a system has been worked out which is reasonably satisfactory, with further improvement easily possible. The recording drums are rotated by synchronous motors driven by alternating current whose frequency is controlled carefully and kept within very narrow limits, by aid of a vibrating reed or tuning fork. With this system at best

DAMAGE TO MISSION SANTA BARBARA, CALIFORNIA.
SHOCK OF JUNE 29, 1925. (CAMERA TILTED SLIGHTLY OUT OF VERTICAL.)

RUINS OF OLD ADOBE CHURCH,
WITH MODERN BRICK VENEER AND FRAME-SUPPORTED BELFRY, SANTA BARBARA, CALIFORNIA:
SHOCK OF JUNE 29, 1925.

we attain the desired accuracy of one tenth of a second, or in rare instances better than this; commonly time determinations are good to two tenths of a second; occasionally they are not better than one fourth of a second; very rarely are they worse than this. Thus when the earth motion produces sharply registered phases, earthquake origins can be located with high accuracy in favorable cases, and very closely in ordinary cases —taking the records of three or more stations into account.

Our stations, equipped uniformly except for additional and auxiliary equipment at the chief station—the Seismological Laboratory—are located at Pasadena, Mount Wilson (at nearly one mile higher elevation), Riverside, La Jolla, Santa Barbara, Haiwee and Tinemaha. For a more completely satisfactory control of the area chosen for study —the region within 500 kilometers, 300 miles of Pasadena—additional stations will be necessary (Fig. 1, p. 337).

The comparison, or correlation, of the time kept by different clocks at the different stations is effected in an ingenious way. At each station there is registered on one recording drum the minute-to-minute time-marks made by the contact-making station clock, written closely parallel with the dot-and-dash signals received from a powerful broadcasting station which is in operation throughout the greater part of the day. Thus, at most times, the clock marks at all stations can be compared directly with the code signals. In this way the clocks are referred to a common relative standard.

since the time errors in registering the code signal are negligible when compared to one tenth of a second.

Although the earth's surface, and its body, must have been shaken at frequent intervals ever since it had a solid crust—the development of seismologic science is of very recent date. Adequate understanding of earthquakes had to wait until there was knowledge of wave-motion in elastic materials and knowledge of geologic mechanics and structure. Earlier views were fanciful or incomplete. In recent years progress has been rapid, but still we know only a little about earthquakes.

We can not pause here to consider the changing status of earthquake knowledge from ancient times onward, giving credit to the very few who mingled sound notions with the confused thought of ancient and medieval days. In the middle of the nineteenth century Mallet and Hopkins cleared the ground and laid foundations upon which Milne and his colleagues, Ewing, Gray and Knott, began to build in the early eighties while they were stationed in Japan. Consider-

THE ARLINGTON HOTEL, SANTA BARBARA, CALIFORNIA.
DAMAGED IN THE SHOCK OF JUNE 29, 1925. (CAMERA TILTED SLIGHTLY OUT OF VERTICAL.)

able progress had been made by them and by their Japanese followers, when, in 1900, Oldham published a classic study based upon collected seismograms of the great earthquake which occurred south of the Brahmaputra River in Assam in 1897, and other shocks. In this paper for the first time it was recognized explicitly and, indeed, fairly demonstrated, that the first two chief phases of the seismogram, which we now denominate P and S, were probably waves of longitudinal and transversal vibration, respectively, propagated along similar paths with different speeds so as to arrive at different distances from the origin at intervals characteristic of these distances. The uniform speed of the third conspicuous wave group, now known to be surface waves, was also recognized. This was a great step forward. Glimmerings of these facts and their relationships had, indeed, been glimpsed before, but without clear recognition or any adequate supporting evidence. For the first time the "elongation" of the seismogram and its complication took on important meaning. Oldham's discovery was followed quickly, and practically independently, by the fundamental work on seismographs and seismograms by Emil Wiechert and Karl Zoeppritz and others working at Göttingen.

Practically without exception the records of earthquakes are complicated, both those of distant and those of local origin. After motion begins to be registered, zigzag or sinuous motion of relatively small amplitude, but with many variations in amplitude and period, is registered for a time, followed, usually somewhat abruptly, by similar complicated motion of larger amplitude, which in turn gives way to a third group of waves of complicated nature of still larger amplitude. Neglecting refinements, these are the well-known principal phases, denoted by the letters, P, S and L—the first, or longitudinal waves, the second, or transversal waves, and the long waves, which travel along the surface.

The "elongation" of the seismogram and its complications—what does this mean? In his epoch-making study Oldham was concerned with the records of a very great earthquake, together with those of sundry other very strong shocks, records written at stations at great distances from the places of origin of the disturbances. At such great distances earthquakes which, near their sources, are perceptible to the senses for a few, or several seconds, or sometimes for a minute or two, more or less, write seismographic records which continue registering for minutes and minutes on end up to durations of three or four hours or even more. As stated already, such records are very complicated, with many sudden or gradual changes in the amplitude and period of the recorded motion. More than this, very small shocks, barely perceptible for a brief instant or not perceptible at all—even near their origins, also write records of complicated nature which continue to be registered for many seconds, and even for several minutes in some cases. What is the meaning of this?

Obviously the recognition by Oldham of the three main groups of waves, P, S and L, propagated from the source with different speeds, affords an explanation, at least in part, for the "elongation" and complication of the written record. It was natural at first to attribute the further observed complexity of the record to enduring action at the source, with continued causation of vibratory disturbance. This was suggested by and appeared to find support from the continued perceptibility of motion near the epicenter. Indeed, in part this must be true. But it is not all the truth.

For example, a record written at Pasadena, of a shock produced by a

—Photo courtesy Portland Cement Association

ALEXANDER HAMILTON JUNIOR HIGH SCHOOL, LONG BEACH, CALIFORNIA. SHOWING DAMAGE TO THE EXIT ARCADE OR CORRIDOR: SHOCK OF MARCH 10, 1933.

large commercial blasting operation at Victorville, California, distant nearly 60 miles from the recording station, is spread out over an interval of more than 30 seconds and exhibits at least eleven conspicuous changes in recorded motion which arrived at later and later times, with perhaps still other phases less certainly recognizable (Fig. 2). Now the disturbance which wrote this record was practically instantaneous in nature—the simultaneous detonation by electrical means of a group of explosive charges buried in a body of crystalline limestone immersed in granite of pre-Tertiary (probably pre-Cambrian) age. At the quarry no motion was perceptible to the senses for more than a small fraction of one second. Here, then, we have a definitely demonstrated "elonga-

tion'' and complication of the recorded motion not due to continued perceptible action at the source. In whatever way the successive phases are explained in detail, it is certain that they represent portions of the vibratory energy propagated with different apparent speeds (probably also with different actual speeds)—and since only four essentially different kinds of elastic waves are recognized (two through the body of the earth and two over the surface) it becomes practically sure that different subterranean paths are involved in the transmission of the numerous phases registered.

Thus, the complication of the seismogram almost surely is due in part to the partition of the disturbance, which may be practically instantaneous at its origin, and the distribution of its motion in transit over many paths along which the motion is propagated with different speeds, so that different parts of the original motion, leaving the origin at the same time, arrive at the recording station at different times. In part, this is known positively to be a fact, from records like that of the blast.

—Photo courtesy of Mr. Donuil Hillis

NORTHWEST–SOUTHEAST CRACK IN GROUND NEAR COMPTON, CALIFORNIA, SHOWING OUTWASH OF SAND WITH INCIPIENT DEVELOPMENT OF ''CRATERLETS'': SHOCK OF MARCH 10, 1933.

Hardly less certain is the case with ''identical'' natural earthquakes (Fig. 3). In the recording both of distant and of local earthquakes, many cases have now been found in which records of two or more earthquakes from practically the same source (probably no two sources are ever strictly the same) are essentially identical, with all or nearly all the peculiarities reproduced so faithfully that the records practically can be superposed—except that the amplitudes are different in different cases. With such records it does not appear reasonable to attribute the elongation and complication of the seismogram to *continued causation of identical nature*. Rather, these effects should be attributed to simple causation with a complication of paths and speeds—conditions which would remain essentially the same in such identical cases.

Thus it happens that the simplest explanation for these facts—which is consistent also with all that is now known, and expected—is a separation of the body and of the rocky crust of the earth into parts, or shells, of different material, differing in density and elastic properties, so that vibratory disturbance is propagated with different speeds in each. In detail, of course, the boundaries between the outermost of these shells must be somewhat irregular, occasionally very much so in particular areas. In the large, however, the material may be considered to be arranged in concentric shells.

The first inkling we had of such a condition came, on the grand scale, from the study of distant earthquakes. To be brief, it was early hypothesized that the earth is made up of a rocky crust, an in-

termediate shell or mantle, and a central core. This was the work of Wiechert and Zoeppritz, following quickly after Oldham's epoch-making discovery. A little later it was amplified and refined by Geiger and Gutenberg. The nature of the intermediate shell and of the core has been the subject of much debate, and, indeed, there is still difference of opinion in the interpretation of data bearing upon this. Also other earth shells have been hypothesized. Some of these have been rejected, while others are still under consideration.

When, therefore, in a study of the collected seismograms of a strong earthquake which occurred in the Kulpa Valley in Croatia, Jugoslavia, on October 8, 1909, A. Mohorovičić encountered a definitely twofold aspect of the beginning of the motion as recorded at stations within a limited range of distance from the epicenter, it was natural for him to seek in explanation a horizontal division of the superficial rocky crust into two parts—an upper one (in which the earthquake originated and in which the motion was propagated with a certain speed) and a lower one (in which the speed of propagation was greater). Thus it could happen that motion passing down into the lower medium could there proceed outward and upward again into the upper layer and so reach the recording station in advance of the motion propagated directly in the upper layer with slower speed. However, the motion first to arrive, having been refracted twice, first upon entering the lower layer and again upon reentering the upper layer, would reach the station with less energy and be recorded with smaller amplitude, as the record here reproduced shows (Fig. 4).

This discovery by Mohorovičić was the next great forward step. Out of it has grown a better understanding, both of the seismogram and of the structure of the earth's crust. The principle recognized by Mohorovičić, and extended

—Photo courtesy Mr. H. M. Engle

CONCRETE COLUMN
IN MARTI'S STORE, LONG BEACH, CALIFORNIA, FRACTURED IN THE SHOCK OF MARCH 10, 1933.

by Jeffreys, also has been applied with suitable modifications to work in geophysical prospecting by seismic methods.

As is often the case with such discoveries—in detail the first explanation required simplification to adapt it to use. From the first it was clear to Mohorovičić that, in each layer, the speed of propagation should increase slowly with depth, with a sudden increase upon passing the boundary into the next deeper layer. In his discussion and formulas he endeavored to take account of this slow increase in speed, as well as the sudden increase. This involved recourse to the integral calculus and solution of an integral equation, yielding formulas of elegant form which, however, were somewhat difficult to use in application to practical cases and, in practise, unnecessarily precise.

It remained for the clear insight of Harold Jeffreys to recognize that seismologic data were not yet exact enough to require so rigorous a treatment. He showed that very simple geometric and trigonometric solutions were quite adequate to deal with the data in practically all cases. His simplification has proved an equally important forward step. Numerous succeeding studies have practically demonstrated that the rocky crust is divided into layers or shells, and that the number of such layers and their thicknesses are not everywhere the same. In certain regions there have been recognized (apart from the uppermost irregular sedimentary bodies) an upper "granitic" or "acid" layer, an intermediate "basaltic" or "basic" layer, and a lower "peridotitic" or "ultra-basic" layer. In these the speeds of longitudinal waves have been found to be approximately 5.5 km per sec, 6.3 km per sec and 7.8 km per sec, respectively—and of transversal waves 3.3 km per sec, 3.7 km per sec and 4.3 plus km per sec. In some areas the so-called "granitic" layer is absent, and there is little doubt that further complexity will be found as knowledge grows.

For example, it already appears that in Southern California the crustal structure is more complex, and it is probable that this is the case elsewhere also. In this connection it must be understood that here we approach the present frontier of knowledge in this field. Therefore, conclusions stated at this point may require modification when more is known. With this reservation—as a result of thorough critical analysis of the seismograms of a group of twenty-one of the local earthquakes in Southern California which had been most certainly located and adequately registered prior to the summer of 1931, Dr. Gutenberg has found a probable division of the rocky crust in this region (apart from irregular, superficial, sedimentary basins, sheets and lenses) into four layers and a substratum with speeds for the longitudinal waves of 5.55, 6.05, 6.83, 7.6 and 7.94 km per sec, respectively; with corresponding values for the transversal waves of 3.23, 3.39, 3.66, 4.24, 4.45 km per sec, respectively. The approximate thicknesses of these layers

14	12	4	9

are 0–14, 14–26, 26–30, 30–39, and greater than 39 kilometers. These find-

—Photo courtesy of Portland Cement Association

THE JEFFERSON JUNIOR HIGH SCHOOL

LONG BEACH, CALIFORNIA; A PORTION OF THE BUILDING WAS IN A STATE OF TOTAL COLLAPSE IN THE SHOCK OF MARCH 10, 1933.

—*Photo courtesy of Portland Cement Association*

CENTRAL SCHOOL, HUNTINGTON BEACH, CALIFORNIA.
BADLY CRACKED WALLS, ORNAMENTAL PILLARS DESTROYED, DÉBRIS AT ENTRANCE: SHOCK OF MARCH 10, 1933.

ings will be the subject of repeated tests as time goes forward.

Theoretically, an elastic wave, upon encountering the boundary between two media of different elastic moduli and different densities, undergoes a transformation into four elastic waves with division or partition of the original energy—two waves reflected at the boundary, one vibrating longitudinally and one transversally; and two waves refracted through the boundary, again one a longitudinal and one a transversal wave. However, under certain conditions some of these vanish, either completely or practically. In spite of this it is obvious that if either the earth as a whole or its superficial rocky crust is divided into two or three or more shells or layers of significantly different nature, reflected and refracted waves must arise, some or all of which will be propagated to the recording stations and there registered. The number of phases thus recorded, and the amplitudes and periods of the motion, will vary with the distance of the stations from the origin and other conditions. In this way the seismogram is still further complicated and in many instances made more difficult to interpret. Thus the earth, and its crust, may be thought of as something resembling in a crude way a complicated prism or set of prisms or lenses, reflecting, refracting, diffracting and dispersing the undulatory energy which spreads outward from the earthquake origin.

Further obstacles stand in the way of straightforward and rapid progress because the region of the shock origin may be, and probably frequently is, multiple in nature or of extended dimensions—thus, in detail, giving rise to different sets of waves independent, in a minute way, in time and place of causation. As a result of all this, the interpretation and measurement of the seismogram—

—Courtesy of U. S. Geological Survey

ROAD BROKEN BY FAULT MOVEMENT
NEAR POINT REYES STATION: SHOCK OF APRIL 18, 1906.

simple and straightforward in theory—at times becomes very complex and sometimes well-nigh insoluble, with the appearance of wave-arrivals, or phases, for which no explanation can be found readily or surely. Fortunately, such extreme complexity is not common enough to halt progress or retard it greatly.

Recognition of definite direct, refracted, reflected and diffracted wave-arrivals (usually differing in amplitude and period)—marking phases of the seismogram—later and later, and more and more widely separated in time, the farther the recording station is from the origin, has made possible the construction of tables and curves or curve-families, showing the times of arrival at different distances or the transmission-times, transit-times or travel-times of these various waves, from which useful and often very accurate estimates of the distance of the shock-origin from the station can be derived.

For distant shocks the first significant diagram of this kind was that published by Oldham (Fig. 5), followed soon after by Milne and a little later by the far more extended and accurate curves and tables of Wiechert and Zoeppritz, which form the basis of all later work. Important contributions to the improvement and refinement of such tables and curves have been made by many workers, prominent among whom are Mohorovičić, Turner, Macelwane, Byerly, Hodgson, Wadati and especially Gutenberg (Fig. 6) and Jeffreys.

A very late curve-diagram of transmission-time for local shocks is that resulting from Gutenberg's study of shocks in Southern California (Fig. 7). It will be clear from mere inspection of this that experience and care is required in the practical utilization of such a diagram in determining the distance of origin of a shock from a given station. As experience grows, this curve-diagram almost surely will be modified. Whether it will be simplified or grow more complex—but more certain—we can not foresee.

From the first, one of the chief objects in our research program has been determination of the geographic location of the epicenters of as many as

possible of the small earthquakes which occur in the region within 300 miles of Pasadena, approximately, and study of the relationships which appear between these and the geologic faults, structures and activity in the same region.

Under very favorable circumstances the epicenters can be located within one or two kilometers; and in a large percentage of cases within 5 to 10 kilometers—but in practically every case the location is an approximation, since the slightly curved, or broken, path followed by the vibratory motion in passing from the region of origin to the recording station can be estimated only approximately, not precisely known. For this reason also, except for possible rare cases of unusually favorable nature, until stations are far more numerous and closely spaced, the depth of the region of origin will be uncertain within limits which may well be different in different cases. Such uncertainty as to depth also affects, sometimes more, sometimes less, the accuracy of the location of the epicenter.

One way of placing the epicenter is that known as the S-P method—in which the time-interval between the arrival of the transversal or S-waves and the longitudinal or P-waves is measured and the distance from the origin to the recording station is approximated by multiplying the time-interval by a number determined empirically by experience or calculated from theory. The rationale of this method is simple—the P-waves and the S-waves in passing from the origin to the stations traverse similar paths at different speeds so that their times of arrival will differ by an amount corresponding to—mathematically expressed, a function of—the distance. Given three or more origin-distances determined in this way, circular ares drawn on a map, using the stations as centers and the origin-distances as radii, will intersect in a small area in or near which the epicenter must lie. This affords an approximation only, since the paths traversed by the P and S waves may not be quite identical (although they can not differ by any very significant amount) and especially, since it often is difficult to determine the time of onset of the S-waves with as high precision as in the case of the P-waves.

A better procedure (which, fundamentally, is the same method) yields the approximate epicentral distance of the station by the careful comparison of the

—Photo courtesy Portland Cement Association

BUCKLING OF CONCRETE PAVEMENT

ON ATLANTIC STREET, RUNNING NORTH AND SOUTH, NORTH OF SIGNAL HILL, NORTH OF LONG BEACH, CALIFORNIA: SHOCK OF MARCH 10, 1933.

—*Photo courtesy Portland Cement Association*

BUILDING AT LONG BEACH, CALIFORNIA,
OCCUPIED BY CONTINENTAL BAKING COMPANY, WHICH COLLAPSED IN THE SHOCK OF MARCH 10, 1933.

phases shown on the seismogram with tables, or curves, of transmission-times for several or many phases. In this way the estimate is not based upon the single time-interval, S-P. Circular arcs are drawn as in the case just discussed. With this method, within small limits, the same origin-time should be indicated at all stations, as read directly from the curves.

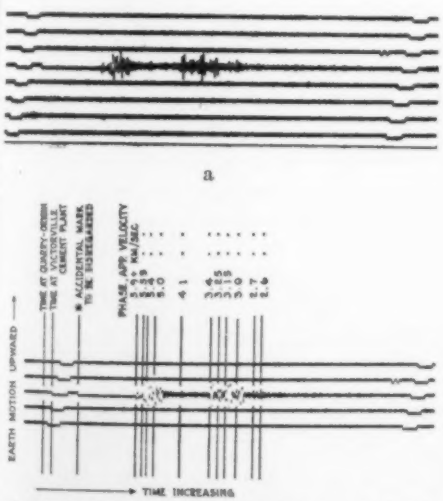
When the data will permit, a still more accurate method consists in the determination of the arrival-times of definitely identified phases at three or

—*Photo courtesy Portland Cement Association*

TOTAL COLLAPSE OF BUILDING AT COMPTON, CALIFORNIA: ANGELES ABBEY MAUSOLEUM, VIRTUALLY UNDAMAGED, IN BACKGROUND; NOTE STREET LIGHT WITH GLOBES INTACT, BUT WITH ONE TOP BROKEN: SHOCK OF MARCH 10, 1933.

FIG. 1. LOCATION OF STATIONS IN SOUTHERN CALIFORNIA

THIS MAP ALSO SHOWS THE COURSE OF THE SAN ANDREAS FAULT, WITH THE SEGMENTS ON WHICH SURFACE FRACTURE OCCURRED IN 1906, AND IN 1857, EMPHASIZED ON HEAVY SOLID LINES.



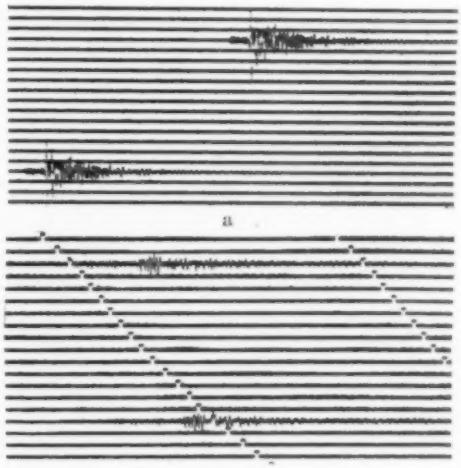
a

b

FIG. 2. RECORD AT PASADENA OF BLAST NEAR VICTORVILLE

DISTANCE NEARLY 60 MILES. (a) FROM ORIGINAL SEISMOGRAM; (b) SHOWING PHASES MARKED.

more stations. The difference between the times of arrival of the *same phase* at two stations, multiplied by the speed of propagation of the motion of the phase in question, gives the difference in distance from the origin of the two stations involved. Knowledge of this difference in distance permits the drawing on a map of a hyperbola or hyperbolic arc, which is the locus of all points more distant from one station than from the other by the amount thus determined (according to the phases used, this hyperbola will be the surface-trace of a hyperboloid of revolution or of a hyperbolic cylinder). The intersection of two or more such hyperbolas will determine the epicenter within limits which depend upon the obliquity of the intersections, as is also the case with circular arcs. In some instances, with both circular and hyperbolic arcs, intersections at depth will help to determine the depth of origin, but frequently the range thus indicated is too great to be useful. Implicitly, this method also as-



a

b

FIG. 3. "IDENTICAL" SHOCKS

FROM PRACTICALLY THE SAME SOURCE AT DIFFERENT TIMES. THE SAME TWO SHOCKS: (a) REGISTERED AT HAIWEE, $\Delta = 40$ KM APPROX.; (b) REGISTERED AT TINEMAHA, $\Delta = 150$ KM APPROX.

sumes that the origin-time is the same at all stations used. This affords a check upon the accuracy of the determination.

Once the epicenter has been found approximately, the accuracy of its location can be improved—when the arrival-times of the P-phase (or of some other *surely* identified phase) are known very precisely—by successive approximations, in which the distances are calculated and the point chosen successively adjusted until a position is found for the epicenter which gives the same origin-time at all the stations used within the limits of error of time- and distance-determination which inhere in the observations and the methods of calculation. In the present state of knowledge this is the best that can be done.

Results of this, as they have been obtained, have been shown on maps exhibited here in the Institution Building for several years past and again this year. Thus far, it appears to be demonstrated by the clustering of earthquake origins along their courses that several of the geologic fault zones are active sources of shocks at the present time. Some, like the local segment of the San Andreas fault, known indubitably to be active sources, have been almost quiet during the last few years. Also many well-determined places of origin are not

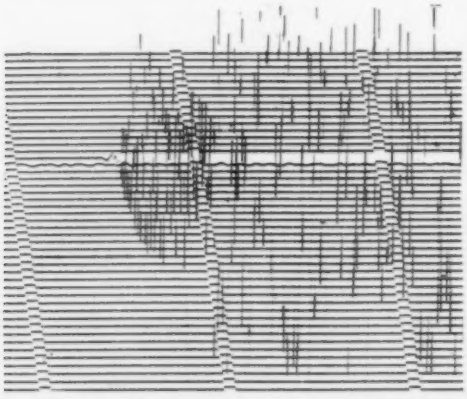
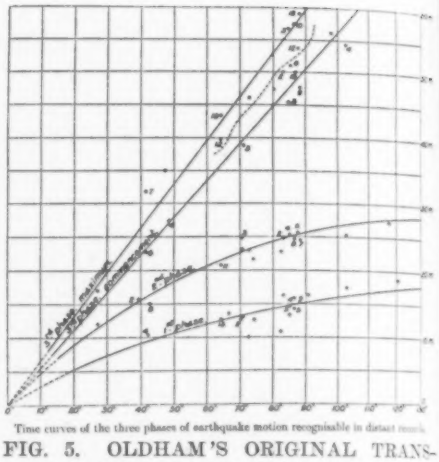


FIG. 4. LOCAL EARTHQUAKE RECORD
SHOWING TWOFOLD ASPECT OF THE BEGINNING.



Time curves of the three phases of earthquake motion recognisable in distant records.

FIG. 5. OLDHAM'S ORIGINAL TRANSMISSION-TIME CURVES
PUBLISHED IN 1900.

associated with any faults known or suspected at the surface. To account for such relations we have several hypotheses in mind, which will require much further testing before safe conclusions can be drawn.

An interesting and important outcome of our work is the development of a *scale of magnitudes* for earthquakes. This achievement is new. Such a scale differs fundamentally from a *scale of earthquake intensity*. A measure of the intensity of an earthquake is, more or less approximately, a measure of the strength or destructiveness or energy of an earthquake at a particular place. Consequently, the *intensity* of an earthquake varies from place to place over the area affected. Of course, the *maximum intensity* in the central region to some extent is directly related to the greatness of the shock, but the local value of the intensity in every case varies from place to place. The magnitude, on the other hand, is a measure of the size of the shock as a whole.

As closely as is practicable all our short-period torsion seismometers are constructed alike. Except as manufacturing difficulties introduce small dif-

ferences, they all have the same dimensions, periods, damping, magnification and so on. Each of our stations has two of these instruments in operation. Theoretically, a given shock will have the same effect upon all these, in general, except for those differences in energy and amplitude, directly due to different distances of the stations from the origin of shaking, which arise from the spreading of the energy and its absorption. In practise—speaking very exactly—the instruments do differ somewhat in behavior because it is impossible to make them all very precisely alike, and, further, the natural ground or rock at the various stations is not the same.

In some places the seismic motion consistently is registered with larger amplitudes, relatively, than at other places,

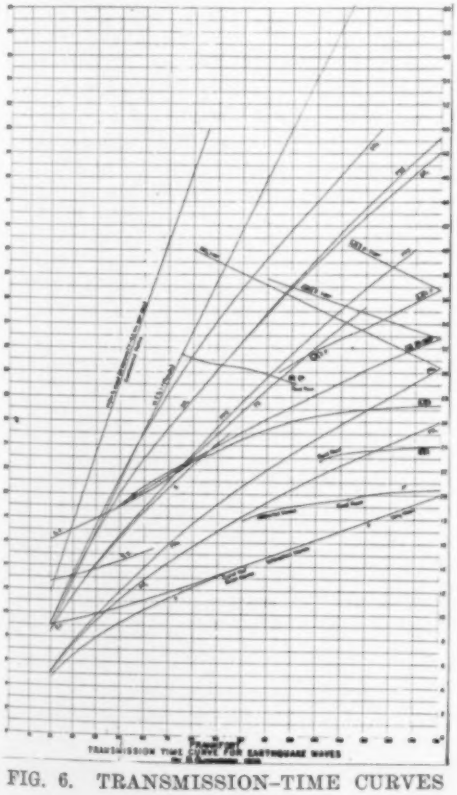
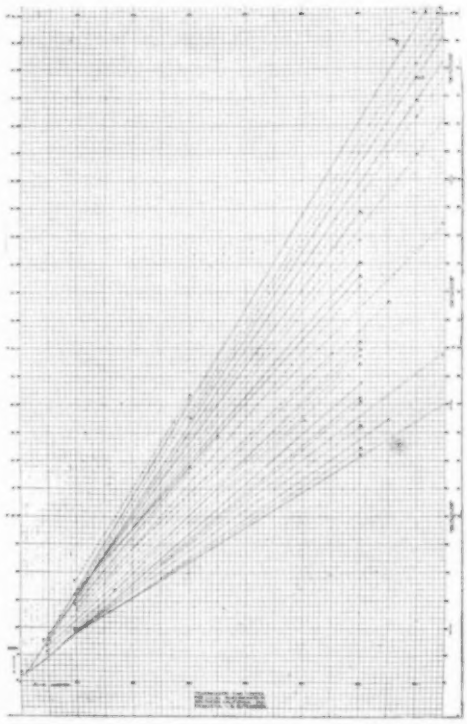


FIG. 6. TRANSMISSION-TIME CURVES AFTER GUTENBERG



—*B. Gutenberg*

FIG. 7. TRANSMISSION-TIME CURVES FOR LOCAL EARTHQUAKES IN SOUTHERN CALIFORNIA

due perhaps to instrumental differences but more probably to differences in foundation ground. In spite of these factors, which render high precision impossible, it is found that comparison of the amplitudes registered at well-determined epicentral distances, with the amplitudes, at the same distances, of a "standard" shock, which have been worked out by successive approximations from sufficient data, yields a value for shock magnitude which comes out the same at all places, within limits of error which are reasonable, even though rather large.

In actual experience the range of amplitudes is so great that the scale adopted is a logarithmic one in which only the characteristic term of the logarithm need be considered. Taking the

small standard shock as the unit, with characteristic logarithm 0 (10^0) 16 degrees of magnitude corresponding to actually observed shocks have been distinguished and recognized already, taking whole numbers and half-numbers from 0 to 7.5, inclusive. Almost surely the greatest earthquakes are of magnitudes still higher than this. The scale is a scale of *registered* amplitude (with essentially identical equipment) in which the defining amplitude for a shock of a given magnitude is 10 times that for the next lower whole number of the scale and 1/10 that for the next higher whole number. Since the energy of the shock varies with the square of the amplitude it follows that the energy of a shock of magnitude 7.5 is 10^{15} times that of the unit standard shock of magnitude 0. The standard shock has been chosen so that it would have a registered amplitude with our torsion seismometric equipment of one micron at the epicentral distance of 100 kilometers with correspondingly greater and less amplitudes at less and greater distances.

On this scale of magnitudes the Long Beach shock of March 10, 1933, works out to be 6, and that of the shock of December 20, 1932, in Nevada, to be 7.5. At this late date the magnitude of the 1906 shock in Central California can only be estimated approximately, but, by comparison with the Nevada shock, it must have been 7.5 at least and probably higher. On this somewhat uncertain basis the energy of the 1906 shock must have been at least 1,000 times that of the Long Beach shock, and almost surely more. As experience with this scale is extended, it may prove possible to arrive at a more positive comparison between these earthquakes, but that given here is probably of the right order.

Within the past five years it has been shown definitely that some earthquakes originate at depths below the earth's surface as great as 400, 500, 600 and more kilometers, in round numbers. A majority of earthquakes, however—a very great majority, if small local shocks are included—originate at small depths, less than 20 kilometers in large part. We do not yet know the cause of deep-focus earthquakes nor whether shocks originate freely at all depths down to the maximum.

Recognition of deep-focus shocks was first clearly voiced by Oldham, but the data at his disposal were not adequate to establish his view convincingly, and he himself pointed out that no adequate mechanism for causing them was known, though he presented suggestions for consideration. Consequently, though his hypothesis was by no means lost sight of among geologists, it did not find any wide acceptance among instrumental seismologists, notwithstanding some support given it in a study published by Pilgrim shortly before the Great War, for the seismographic criteria had not then been clearly recognized. Events have proved Oldham right in his general view, but he reached corollary conclusions which do not seem to find convincing support.

After the death of Milne, Turner, upon taking up the work of the assembly and digest of earthquake reports which is published in the International Seismological Summary, began to find peculiarities in the times of arrival of phases on the seismograms in certain cases which, *if they were correctly interpreted and measured by the reporters,* would point to origins at great depth for the shocks in question. However, he also found other cases in which the data reported to him would point to "high focus," some of these apparently indicating origins above the surface of the earth. This latter absurdity, together with general knowledge among working seismologists that phases frequently were wrongly interpreted by some of the

less experienced workers, kept this view of Turner's from making headway among seismologists generally, since it was known that he did not have direct access to the actual seismograms, but necessarily was restricted to the interpretations and measurements made and reported by others. Other early divergent views of his, based upon these station reports, later brought into accord with general knowledge, plainly rested upon imperfect data. So, while it is now known that Turner was right in many instances of deep-focus shocks, in many others he was led to wrong conclusions by inaccurate information. His view did not prevail at first, nor until later work brought support of it.

Thus it was left for Wadati, in a paper published in 1928, to establish the fact of the occurrence of deep-focus earthquakes, by methods and data satisfactory alike—after verification—to instrumental seismologists and to students of earthquakes who follow older, field methods. Subsequently, Scrase and others have confirmed the occurrence of such shocks and extended our knowledge of their seismographic phases and transmission-times. Among other things such shocks are characterized chiefly by the registration of early reflected phases, thrown back from the surface of the earth—and the virtual absence of large surface waves, a criterion pointed out by Lamb on theoretical grounds much earlier.

It happens that our own vertical-component instruments and some of our special auxiliary apparatus are unusually well suited for registering these shocks recognizably, and since the establishment of their reality and the discovery of the criteria which distinguish them, we have found that their occurrence is by no means a rarity, though they are fewer in number than normal shocks. In this connection it is interesting that Zoeppritz more than 20 years ago recognized a difference between the records of these and of normal distant shocks but did not hit upon the explanation. The records of such shocks were long considered to be the incomplete registration of very distant earthquakes. Thus far the origins of these shocks appear to have been limited narrowly to the Asiatic coastal region and nearby mainland, with a few located in Western South America, and fewer still in Central Asia.

Although in our research program emphasis is laid primarily upon investigation of the local earthquakes which originate in the Southern California province, at the Seismological Laboratory in Pasadena we operate some routine instruments and some auxiliary apparatus especially adapted for the registration of distant shocks. We thus contribute our share to the data necessary for progress in this part of the field. Also we are engaged in a systematic detailed study of the records of three major distant earthquakes borrowed from a great number of the stations which make up the world-wide network. The experience gained from such studies is essential for the investigation of such larger shocks as may originate in or near our own province.

An interesting and important field has been opened up by promising experiments which have been made with explosives and field seismographic equipment like that used in seismic prospecting—with a view to determining, by the registration of reflected and refracted waves, the depth and attitude of strata or rock bodies within the superficial crust competent to produce such reflections and refractions. For the uppermost part of the crust excellent results have been obtained, but as yet only uncertain findings have resulted, for the most part, from the lower part.

As stated in the beginning, our work in a sense is a sequel of investigations

stimulated by the occurrence of the 1906 shock in Central California.

One important outcome of the detailed study of that shock was the great emphasis which it laid upon the fact—previously recognized on many occasions—that, other things being equal, the destructiveness of an earthquake within the area near to the origin is related in a very intimate way to the nature of the ground at the surface—great apparent intensity or violence (as measured by destructive effect) being manifested upon "made" ground and loose natural alluvium, *especially when thoroughly charged with water,* with comparatively slight apparent intensity upon firm rocky ground at the same or comparable distances from the source of shaking. Intermediate effects were exhibited on ground of intermediate quality.

Experience in later shocks has abundantly confirmed this finding—in an especially striking way in the recent Long Beach earthquake for which the area outstandingly marked by damage in unsuitably designed structures corresponds almost exactly with that portion of the deeply alluviated Los Angeles plain where ground water reaches nearly or quite to the surface. However, it may be noted in passing that structures suitably designed and well built withstood the shaking well even on such ground, since the shaking only attained minor destructive power on this occasion.

Though the relation was less striking, similar findings prevailed in the cases of the Santa Monica earthquake of August 30, 1930, the Whittier shock of July 8, 1929, and the Santa Barbara shock of June 29, 1925—as well as others more remote. The outstanding association of greater apparent violence with loose wet ground has led many, including some trained geologists who are not specialists in earthquake study, to seek the origins of shaking in places aside from those indicated by instrumental findings. It may be well, therefore, to emphasize the fact that in two instances we have exceptionally well-determined positions for the shock origins, in both of which the field data tend to be misleading to students of small experience, or persons who do not examine all the facts critically.

In both the Santa Monica shock of August 30, 1930, and the Long Beach shock of March 10, 1933, the place of origin happened to be situated almost exactly equidistant from two of our stations, a fact which severely limited its geographic position. In both cases the data of all the stations indicated epicentral areas of very small dimensions consistent with these conditions of equidistance. It seems probable that we know the positions of the origins of these shocks within one or two kilometers. If the uncertainty is larger than this, it is still very small.

Notwithstanding this, in both these cases, and in others also—foundation ground and quality of building aside for the moment—the greatest apparent intensity was manifested not immediately at the epicenter but a little distance away from it. This observation, together with other circumstances, leads to the tentative conclusion that destructiveness and the apparent intensity based upon it are closely associated with waves at the surface, possibly elastic waves, possibly quasi-gravitational waves, possibly both in turn, and that these, as indeed theory suggests, do not have their genesis or their maximum development at the epicenter but at a little distance away from it, either symmetrically around it or otherwise, according to the specific nature and action of the causative mechanism. The distribution of effects also sometimes suggests analogies to an interference pattern due possibly to different constructive and destructive combination of waves at different places. Proof

of this suggestion is exceedingly difficult.

There remains for further brief consideration the Long Beach earthquake of March 10, 1933. It is, of course, a fact that this shock caused by far the greatest loss of life, the most numerous injuries to persons and the largest financial loss and destruction of property ever occasioned by earthquake in Southern California. Notwithstanding this, the Long Beach shock was by no means the greatest earthquake, in point of magnitude, nor the strongest one, in point of intensity, which has visited the same immediate district during the time, less than two centuries, since white men came to occupy it. Both in magnitude and in intensity the shock was comparable with that which laid Santa Barbara low in 1925—perhaps a little greater, perhaps a little less. Nevertheless, it was, probably, the most considerable shock to occur in the same immediate neighborhood in nearly eighty years. This long interval of relative seismic immunity, combined with a gentle climate (no hurricanes, no tornadoes of any magnitude, hardly ever hard gales, rare floods, no heavy snows), a wide plain of loose, deep, water-soaked alluvium and low hills of uncemented sediments and a phenomenally rapid influx of population in the last two decades, resulted in numerous considerable towns, villages and cities—assemblages of houses, shops, industrial plants and other works of construction ill-designed and badly built to withstand any severe or unusual stresses. This was true especially of business buildings and unfortunately of schools, churches and other public and semi-public places of assembly. Consequently, when fairly hard shaking came again the result fell short of a great disaster only by good fortune—a good fortune which has now been repeated several times in California in connection with nearly all the greater shocks which have occurred there.

By every criterion known, the shock of March 10, 1933, fell short of being a great earthquake—duration, intensity of shaking, size of the area in which damage occurred, size of the area of perceptibility and the distance to which it was well recorded by seismographs. It was, however, a moderately large, fairly strong local shock. Its characteristic maximum intensity was VIII of the 1931 Modified Mercalli scale, VIII plus to IX of the Rossi-Forel scale so long in use. There were a few small scattered places where intensity IX of the 1931 scale may have prevailed. The damage, injury and loss of life were due in overwhelming measure to bad or wretched building, or to bad or wretched natural or artificial foundation ground, and to both in combination.

Nevertheless, we must go back to 1857 or 1855, and perhaps to 1812, for a shock of comparable strength affecting the same area.

The shock of 1857, originating in slipping along the south central to southern segment of the San Andreas fault (Fig. 1) for a distance of 200 miles or more, was a great earthquake. Probably it somewhat exceeded in magnitude the 1906 shock in Central California, but *its intensity in the Los Angeles plain* may not have risen so high as that in March, 1933.

The shock of 1855 was strong in the same immediate region. "Almost every structure in Los Angeles was damaged, and some of the walls were left with large cracks. Near San Gabriel . . . (an) adobe . . . was wrecked, notwithstanding that it had walls four feet thick with great beams of lumber . . ." Changed conditions make it impossible to compare this shock with that of March, 1933, more closely.

There seems little doubt, however, that the shocks in the autumn of 1812 were both greater and stronger than that of March 10, 1933; and the probability is very strong that the shock of

July, 1769, was also stronger in the Los Angeles plain than the shock of the year 1933.

Within narrow limits the source of the March, 1933, shock was three and one-half miles off-shore southwest of Newport Beach in the course of the Inglewood fault zone projected southeastward. Since moderately hard shaking continued for 10 to 15 seconds, it is probable that the region of origin underwent some enlargement during the interval. But all investigations carried through thus far indicate that such development was not extensive.

Aftershocks were very numerous, instrumental registration being continuous for many hours with the more sensitive apparatus at Pasadena some fifty miles away from the source. The maximum registered amplitudes of the largest aftershocks were less than 4 per cent. of the maximum registered amplitude of the chief shock on the strong-motion records at Pasadena. For many of the aftershocks, especially those which occurred soon after the main shocks, the places of origin were very close to that of the main shock. Others, however, especially later ones, were located at various distances away from the original source, up to 15 or 20 miles, both to the northwest and to the southeast. Our study of these is still in progress. Conclusions based on our present knowledge of these would be premature.

While aftershocks usually fall off in number and size rather rapidly, depending somewhat on the size of the chief shock, it is, of course, difficult to determine when their course is completely run until the lapse of time has been sufficient to develop the picture fully.

Consequently, it is difficult to state with certainty whether the sharp shock of October 2, 1933, should be regarded as an aftershock or as an independent earthquake. In any case it was stronger than any of the sure aftershocks which followed the shock in March, but only a little stronger than the larger immediate aftershocks. Its origin was located some 17 miles to the northwest of that on March 10—near the southeast end of Signal Hill, also in the zone of the Inglewood fault.

It is otherwise with the smaller shock of October 24, 1933, which, nevertheless, was a sharp earthquake. This shock originated about one-half mile north of the village of Downey—very probably on that fault which was the source of the barely destructive Whittier earthquake in July, 1929, at a point further west than the earlier shock.

This brings the record up to date, as nearly as possible, and gives, I hope, a reasonably clear picture of the work we are doing and of its trends and purposes in the field of science and for human welfare.

YOUR NOSE KNOWS[1]

By Dr. MARSTON T. BOGERT

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No other sense is so marvelously acute as that of smell, so widely and extensively connected with other brain centers, or so potent in awakening our memories and our emotions.

The amount of an odorous substance necessary to produce the sensation of smell is incredibly minute. Camphor is said to be detected in a dilution of one part in four hundred thousand, musk one in eight million, and vanillin one in ten million. Valentin[2] found that one twenty-thousandth of a milligram of otto of rose was all that was required. Fischer and Penzoldt[3] determined that one 460-millionth of a milligram of the rotten egg odor of ethyl mercaptan was the approximate minimum amount which, coming into contact with the olfactory nerves, could be immediately recognized by them, which is about 250 times less than the minimum amount of sodium which can be detected by the spectroscope, according to the experiments of Kirchoff and Bunsen.[4]

The pleasant odor of the soil was ascribed by Berthelot, the distinguished French chemist, to traces of an unidentified camphoraceous body of so powerful a fragrance that even a trillionth of a milligram gave a clearly perceptible aroma.

It is also one of the senses particularly susceptible to "adaptation," *i.e.*, a diminution or cessation of the sensation in spite of the continuance of the stimulus, a phenomenon probably akin to fatigue. Both individuals and odors show widely divergent behavior in this respect. Some odors quickly fatigue or benumb the sense of smell in nearly all persons; whereas, with other smells, only a few individuals will gradually lose their ability to detect them while remaining in the same atmosphere. This is the great danger of hydrogen sulfide, for it quickly paralyzes the sense of smell and the victim may not be aware that he is being poisoned until he suddenly falls to the floor unconscious.

Some people may be indifferent to music, but those unaffected by odors are rare indeed. A breath of perfume brings instantly before our vision past scenes with all their pain or pleasure. From certain odors we recoil instinctively, not because they are intrinsically unpleasant, but because of the associations they recall; while others, perhaps unattractive to our fellows, possess a peculiar fascination for us. The recognition of a perfume is instantaneous, as is the picture it conjures up.

Goethe visited Schiller one day and, not finding him at home, waited in his study, where he sat down to a table and began to write a few notes. Gradually he felt increasingly sick and faint. Frau Schiller inquired the cause of this sudden illness, and the poet said he thought that it was due to a peculiar odor in the room. Whereupon she opened a drawer full of decayed apples and took them away. Afterwards she explained that for some mysterious reason the odor of rotten apples stimulated Schiller and he couldn't do his best work without it. So that what caused a profound constitutional disturbance with Goethe was a beneficial stimulant to Schiller.

Oliver Wendell Holmes wrote that "memories, imagination, old sentiments

[1] An address presented at the meeting of the American Chemical Society, St. Petersburg, Florida, on March 27, 1934.

[2] *Lehrb. d. Physiol.*, II, 2, 279, 1848.

[3] *Ann.*, 239, 131, 1887.

[4] *Pogg. Ann.*, 110, 168.

and associations are more readily reached through the sense of smell than by almost any other channel," an opinion in which Kipling concurs when he says "Smells are surer than sights or sounds to make the heartstrings crack."

Holmes also has written:

> Perhaps the herb everlasting, the fragrant immortelle of our autumn fields, has the most suggestive odor to me of all those that set me dreaming. I can hardly describe the strange thoughts and emotions that come to me as I inhale the aroma of the pale dry rustling flowers. A something it has of sepulchral spicery, as if it had been brought from the cave of some great pyramid, where it had lain on the breast of a mummified Pharaoh. Something too of immortality in the sad, faint sweetness lingering so long in its lifeless petals. Yet this does not tell why it fills my eyes with tears and carries me in blissful thought to the banks of asphodel, that border the river of life.

Or, to quote Bret Harte:

> But the smell of that subtle, sad perfume,
> As the spiced embalmings, they say, outlast
> The mummy laid in his rocky tomb,
> Awakens my buried past.
>
> And I think of the passion that shook my youth,
> Of its aimless loves and its idle pains,
> And am thankful now for the certain truth
> That only the sweet remains.

The literature of all civilized countries is replete with similar illustrations.

The allure and fascination of perfumes have been more potent factors in the rise and fall of empires than most of us realize. Anthony sacrificed his empire and his life to the seductive aromatic Cleopatra. The Medicis were famous for their perfumes and infamous for the way in which they used them to mask the deadly poisons with which they eliminated their enemies. One of the carefully guarded secrets of the British royal family is said to be the formula of a specially prepared perfume with which Buckingham Palace is sprayed for the Court presentations attended by distinguished men and women from all parts of the world. This perfume is believed to be entirely original and suggests a tropical flower garden. It has been used since the time of Queen Victoria's first Court, and its composition is said to be known only to the King and Queen, in addition to the manufacturers themselves.

That the English Parliament of 160 years ago must have been seriously concerned about the use of perfumes seems to be indicated by the law which they enacted during the reign of George III, in 1774, the same year in which Priestley discovered oxygen and that the First Continental Congress assembled in Philadelphia. This law stated that:

> All women, of whatever age, rank, profession or degree, whether virgins, maids or widows, that shall from and after this act impose upon, seduce and betray into matrimony any of His Majesty's subjects by the use of scents, paints, cosmetics, washes, artificial teeth, false hair, Spanish wool (impregnated with carmine and used to this day as a rouge), iron stays, hoops, high-heeled shoes or bolstered hips, shall incur the penalty of the law now in force against witchcraft and like misdemeanors, and that the marriage, upon conviction, shall stand null and void.

How much we depend upon the nose to distinguish between healthy and diseased individuals, between sanitary and unsanitary conditions! How frequently it warns us against pollution of air, food or drink, against pestilence, hazards and dangers of all kinds! And yet we repay this debt to the sense of smell with quite general indifference and scorn. When the nose is powerless to help, as in the case of such deadly gases as carbon monoxide, our life is in immediate jeopardy, as witness the recent asphyxiation of nine students in a Dartmouth fraternity house. There is a real danger that, through long-continued disuse and neglect, we may some day lose our sense of smell entirely.

Plumbers to-day still use occasionally the time-honored method of locating leaks in the plumbing by introducing oil of peppermint and then sniffing along the pipes.

The chlorophenols have such powerful and distinctive odors, of rank carbolic type, that they have been employed successfully to trace stream pollution. Professor Holleman of Amsterdam, when he was working upon such products several years ago, told me that he happened to be shopping one day in a busy part of the city, when he was suddenly startled by the recognition of this familiar chlorophenol odor, and looking up the street to windward, saw, many blocks away, his assistant coming toward him, who proved to be the undoubted source of the odor.

The reason why the sense of smell in the case of animals was the first of the special senses to be extensively developed was probably because they, especially the quadrupeds, depend more upon scent than upon sight to warn them of impending danger.

The fetid excretions of many insects and other animals, when not of sexual significance, are probably intended for defensive purposes and, so far at least as our friend the skunk is concerned, I think that we will all agree that the defense is an effective one.

Man has occasionally made use of the odor sense of animals for his own protection. An interesting case was cited not very long ago in which an intelligent plumber was called to locate the source of an evil smell in a London store. Examination of the room failed to disclose the location of this smell and a study of the plans of the building failed to show any plumbing work in the room. Later, as the result of additional complaints that the foul odor was making many of the women employees so ill that they could not stay in the store, a further examination of the room was made with similar lack of success in locating its cause. The plumber then had a bright idea and went to a neighboring butcher shop, where he caught a bottle full of blow-flies, knowing that they are always attracted by such odors. These were released in the troublesome room to serve as detectives, and before long had all settled upon the same portion of the wall in one corner of the room. When this wall was opened, an old foul drain pipe was found which had been there for years and completely forgotten.

In the case of many animal forms of life, their predilection for special odors has been used with considerable success to attract to their destruction not only mammalian pests, but insects as well. In this way the geranium perfume (geraniol) has been used as a lure for the dreaded Japanese beetle, which it will attract from distances of a mile or more, and when these beetles reach the source of the odor they find awaiting them a very tasty meal of poisoned molasses. Similarly, an odorous constituent of the cotton plant, trimethylamine, has been used to attract the boll weevil, the object of such efforts of course being to induce the insects to collect in vast numbers where they can be killed *en masse*. A letter recently received from an investigator in the University of Western Ontario may be of interest to a fruit-growing state like Florida. It runs partly as follows:

> I am endeavoring to determine what constituents of the quince, peach and apple are attractants for the Oriental fruit moth, and we are basing our work on the assumption that insects detect odors which are perceptible to man. . . . I find that Power and Chesnut, of the Phytochemical Laboratory at Washington, have done considerable work on the apple and peach, but have been unable to find reference to work of a similar nature on the quince. This latter fruit is much more odorous than either of the others and certainly more attractive to the Oriental fruit moth.

Not long ago, I was visiting a farmer near South Bend, Indiana, who is, I am informed, the chief distiller of native essential oils in that part of our country. In addition to peppermint and seven or eight other oils, he often distils some catnip, because he said there was considerable demand for this last oil

from residents of the mountainous districts of the West and Southwest, who use it on the meat with which they bait their traps for mountain lions. Apparently, therefore, this odor has a special appeal not alone to the domestic cat, but to other members of the feline tribe as well.

Even the attitude of the hard-boiled business executive towards the use of perfumes in merchandising has changed strikingly during recent years, and has now given place to the slogan "Sell by Smell."

The *Daily News Record*, of New York, recently had the following to say on this subject:

> The nose is a greater factor in business today than price, quality or quantity.
>
> The advertising man writes a great deal about the glories of his merchandise, but the consumer gets going when he smells something he wants.
>
> His nose knows!
>
> The New York nostril has become tremendously sophisticated. The restaurants that say it with garlic are responsible to a great extent, it is claimed.
>
> Men marry perfumes rather than women today. They take out a license when they encounter an extract they think they could endure at the breakfast table every morning for 40 years.
>
> Shoes, leather and luggage, not to mention perfumes with a platinum price, sell largely because their aromatic qualities intoxicate.
>
> A deal is closed and the goods practically delivered when the customer's nostrils begin to twitch like a setter's.
>
> Olfactory orgies are not confined to women. The men sometimes keep it up until they have to be assisted to a taxi.
>
> Some men even fiddle around drug departments in the hope that they will encounter an odor good for a misunderstood husband.
>
> The girls no longer care who pays the rent if they can find a husband to keep them in imported perfumes.
>
> People who object to paying about $60 a month to the landlord will pay that much for a bottle of perfume.
>
> The diner-out turns to the right when he walks into a miasma that overcomes his powers of resistance.
>
> The women manage to arrange a spree without a headache by going from one perfume counter to another, coaxing whiffs out of the various demonstrators largely responsible for the mixed odors of subway trains, department store elevators, etc.
>
> Just as men formerly went from one cafe to another testing the hospitality of favorite Fausts, the women saunter from one store to another mixing their extracts.
>
> The men are frequently slightly incoherent after applying their pet theories regarding the chemical properties of liquids and the women are usually a trifle irresponsible when they conclude their afternoon inhalations. A woman to-day must learn to be careful how she mixes her perfumes.
>
> In the luggage departments the patron sniffs the grip of no regrets and if the odor is soothing there is a readiness to buy that would not otherwise be noticeable.
>
> Russian leather, like Russian tea and vodka, acts immediately. The nasal organs whisper a message to the brain and the deal is closed while the customer is in a coma.
>
> There are people who would rather stand around luggage departments than linger in an old-fashioned rose garden.
>
> Parma violets are cabbage compared to the pungent qualities of a first-class luggage department.
>
> The writer took note of several men buying new spring shoes a few days ago. Four out of five sniffed the leather before they even permitted a fitting. Mildly imbecile expressions scampered over their countenances when they encountered a favorite scent.
>
> Experienced shoe men contend that you can lead a man to a leather but you cannot make him like the odor.

Shrewd business men are thus awakening to the powerful sales aid to be obtained from perfumes, and at last understand that an appeal to the nose is often far more potent than one to the eye. The actual value in cold cash of the despised sense of smell has been too often wholly overlooked or ignored by the high pressure salesman as well as by the head of his concern, neither of whom seems to have grasped the fact that scents may make dollars.

The sales appeal of perfumes may be utilized either to draw favorable attention to a normally odorless product, or to overcome a disagreeable smell. When a disagreeable odor can not be removed or destroyed, the only alternative is to

mask it by perfumes. Many markets are closed to malodorous products which would be opened immediately upon the removal of that objectionable feature. The total value of sales annually lost through failure to recognize these facts runs into many millions of dollars.

In the case of a product of established reputation and characteristic odor, it would probably be just as disastrous to change that odor as it would be to alter the form of the package or the trade-marked name.

When a prospective customer picks up a cake of toilet soap or a package of cosmetic, her first impulse is to smell it. If the odor pleases, the other merits of the goods are likely to be inquired into, whereas if the goods are odorless or carry no special appeal, the examination usually goes no further. The first attempts to sell camels' hair shawls manufactured in Europe failed because these famous shawls as they were received from India exhaled a peculiar and characteristic odor which enabled even the inexpert to distinguish between the Indian and the European product, until it was discovered that this odor was due largely to oil of patchouli, and when this deficiency was made good in the case of the European product, its market expanded immediately.

The sale of a house may be decided by whether it smells old and musty or sweet and clean with the odors of new woods, fresh paints, fresh varnish and the like.

In the opinion of the manufacturers, the judicious use of appropriate and delicate perfumes and the air of luxury thus created have often determined the sale of their high-priced automobiles quite as much as the persuasive eloquence of the salesman.

In certain theaters, perfumes have been and still are at times disseminated throughout the entire auditoria by introducing them into the ducts of the ventilating systems; but the proposal to change these odors during the course of the performance in such fashion as to depict the changing moods presented upon the stage is practically impossible, because of the difficulty of completely replacing one atmosphere by another with sufficient speed. A musty upholstery in the theaters not infrequently has deterred patrons from returning. The use of incense in religious services is not only good ritual but excellent psychology as well.

Quite recently a very interesting upholstery material has been developed and already enjoys a considerable sale. It is manufactured by taking pig hair and subjecting it to the action of a mechanical "picker," which separates and fluffs up the hair so that when sprayed with rubber latex every individual hair will be coated completely. By simultaneously drying and curing, there results an exceedingly light, tough and springy felted mass of rubberized hair which has found an immediate market. Since both pig hair and rubber latex have unpleasant odors, it is doubtful if a pound of this new and useful product could have been sold if the manufacturers had not had the good sense to cancel this bad odor by the judicious use of perfume. The incorporation of less than one tenth of one per cent. of perfume achieved this at a negligible cost.

The clothy or faintly rancid smell of fabrics is generally to be ascribed to the oils and pastes essential to the weaving process or to give luster, smoothness or scroop to the finished goods (Turkey Red oil). This odor may be suggestive of castor oil and sulfur, and in the course of time tends to become more rancid. The use of suitable aromatics will readily and economically replace any initially unpleasant odor by a pleasant one and can also inhibit the development of rancidity. Perfumes especially designed for this purpose are now on the market. High-grade silk stockings are often faintly perfumed to increase their appeal to the prospective customer.

Scented cloth linings for bureau drawers, in place of sachets, are also available.

A field where there is still room for considerable improvement is that of the moth-proofing and insect-proofing of fabrics of all kinds, such as furs, carpets, etc. In the light of recent discoveries, it should be possible to accomplish this without leaving the goods permeated with objectionable smells. Of course, in the case of furs this has been avoided by simple storage at low temperature. Certain dyes have been discovered which are claimed to be effective insect-repellants. The fabrics dyed with such chemicals are neither malodorous nor ever in danger of insect attack.

It has proven a comparatively simple problem to incorporate in cleaning fluids chemicals which leave behind an agreeable aroma instead of the disagreeable odors hitherto so much in evidence when gloves, dresses and other clothing returned from the cleaners. Even perfumed laundry starch is now on the market.

The so-called Russia leather has always had a special appeal for me and possibly for others, not because the leather itself is any better than other brands, but because of the agreeable scent imparted to it by the birch oil used in its preparation. Several manufacturers of artificial leathers are scenting their products to make them smell like genuine leather at a cost of about $7.00 per 10,000 yards. Shoe dealers have had their goods either returned or have lost customers because of strong-smelling leather.

Linoleums, oilcloths and similar floor coverings are largely linseed oil products, and the odor of that oil is unpleasant to most people. The manufacturers at first went to considerable expense to lacquer the surface of the linoleum, so as to seal up the offending smell. Now they find that a better and a much cheaper way is to use such aromatics in the process as will either completely eliminate the bad smell or replace it with a faint and agreeable one.

The odor of printing inks is often fishy and rancid from the oils used in their manufacture, and this is especially objectionable when used on food packages, for many foodstuffs absorb odors with great avidity and the appeal of a product entirely satisfactory in all other respects may thus be completely destroyed and the sale of the product seriously injured. Such difficulties are easily overcome by the perfume expert. A Middle West meat packer has the Cellophane wrappers for his prize bacon packages printed with inks which themselves possess a bacon aroma. Makers of chewing gum and of confections are also printing their wrappers with inks perfumed in such fashion as to reinforce the olfactory appeal of the goods.

It has been suggested in connection with the matter of scented printing inks that a publisher might find it to his advantage to have his publications recognized not only by their general appearance but also by their characteristic odor, so that his books on scouting and woodcraft, for example, might be given a piney or woodsy fragrance, his detective stories the mysterious and piquant aromas associated with the high-class female criminals of such tales, and his love letters the heavy seductive narcotic perfumes of the languorous Orient.

Some books, the rotogravure sections of many newspapers and a number of handsomely illustrated magazines have rank cheesy odors, due in part to the casein used in the coating mixture, which bad odors should be eliminated as far as possible, and the remaining traces neutralized by perfume, just as traces of yellowness are corrected by suitable blueing.

The cost of imparting a pleasant odor to goods which are either odorless or

malodorous is usually very little and is more than repaid by the increased sales which result. According to the executive manager of one of our leading perfume houses, ten dollars' worth of perfume will scent 35,000 pounds of paper and enable a magazine publisher to get out an issue which any reader will be glad to hold close to his nose instead of having to sit by an open window with the breeze blowing away from him.

In some manufactures an odor specification for the raw materials would be immediately helpful. The kind of aroma to be imparted to a product should of course be appropriate, and need not always be of a floral character. Less than one cent's worth of perfume will completely mask the disagreeable smell of a gallon of glue, whereas in the case of a high-grade perfumed toilet soap it may cost several cents per cake.

In the matter of odor, manufacturers of household lacquers have markedly improved their products, and the producers of raincoats, wall finishes and other similar articles could profit greatly by their example.

A well-known company makes lamp shades by a process in which gelatin is used. In damp weather molds tended to grow on this gelatin and form black spots. The addition of a small amount of carbolic acid during the process prevented the growth of these molds, but on the other hand left an unpleasant odor. The company is therefore using a perfumed material as a sterilizer so that the lamp shades possess a pleasing faint aroma.

The determination of the particular perfume best suited to mask a given odor naturally requires skill and some experimentation. Certain fly sprays, composed of kerosene and pyrethrum powder, used to be scented with from 5 to 6 per cent. of oil of wintergreen. Such sprays can now be scented just as satisfactorily with two tenths of one per cent. of a different aromatic.

The rapid recent increase in the popularity of some brands of cigarettes is ascribed to the impregnation of the tobacco with small amounts of coumarin, whose odor may be likened to a combination of vanilla and new-mown hay; just as saccharin is added to other types of tobacco, notably the so-called plug cuts, to impart added sweetness of taste.

A certain Illinois department store, the majority of whose customers are women, encloses a perfumed "Thank you" with its receipted bills; and there is a subtle psychology about the practise of a Connecticut fire insurance company which solicits business by means of a folder exhaling the wet, burnt wood smell characteristic of a house which has been ravaged by flames.

Not long ago the Chicago Museum of Science and Industry wrote us that they had completed the installation of a model mine and wished to introduce into its ventilating system an odorous material which would impart to the mine air the damp, earthy smell characteristic of such shafts and tunnels. The problem was referred to a well-known perfume house, who have solved it, I understand, to the entire satisfaction of the museum authorities. Those of you, therefore, who have recently visited that museum in Chicago and have gone down this mine shaft, have breathed there this atmosphere without knowing that it was a synthetic one provided by the organic chemist.

The Huddersfield Line in England have perfumed their buses in some cases with pine and in others with rose or with violet, because they believed these three odors to be the most popular and because such treatment tended to eliminate the body odors which otherwise might be too much in evidence.

That their judgment as to relative popularity of odors was approximately correct is supported by the results of a most interesting questionnaire sent out some time ago to a large number of

people by the Cramer-Krasselt Company, an advertising corporation of Milwaukee, Wisconsin, asking their opinion on a list of 55 different smells. Through the courtesy of Mr. Aumueller, the manager of their direct service department, the results have been made available. The questionnaire was admirably simple and direct. All it asked in the case of each odor was that the voter should indicate whether he liked, disliked or was neutral (indifferent) to it. The odors preferred, in order of choice, taking only the first 10, were: (1) rose (85 per cent.), (2) pine (83), (3) lilac (83), (4) violet (77), (5) lily-of-the-valley (77), (6) coffee (76), (7) balsam (76), (8) cedar (73), (9) strawberry (68), (10) wintergreen and apple (67). Those disliked, arranged similarly, were: (1) perspiration (97 per cent.), (2) garlic (92), (3) rubber (81), (4) lard (79), (5) kerosene (77), (6) olive oil (70), (7) fish (70), (8) onion (66), (9) turpentine (63), (10) gasoline (59).

There will probably be quite general agreement as to the appropriateness of giving perspiration a high place in such a list, but there are many, especially in southern Europe, who certainly know their onions and who do not feel at all the same way about garlic, and the rubber manufacturers, handlers and dealers were inexpressibly shocked to learn that their product vied with perspiration and garlic in public dislike so far as its odor was concerned, for to them it had never seemed objectionable in the least. Not long thereafter, representatives of the rubber industry held a banquet in New York, at which boxes of red rubber bands of lilac fragrance were distributed, and rubber coasters with the odor of new-mown hay were used for the glasses, to show that the old familiar rubber smell could be very easily replaced by more agreeable ones. Less than one one-hundredth of a cent's worth of perfume will perfume an entire box of rubber bands.

The odors of towns and cities often constitute some of the most vivid recollections of a traveler. In my own case, for example, and I am equally certain concerning my wife, the most striking and lasting memory of Algiers is that of the smells of the Kasba or native part of the city.

Of the many problems still to be solved in this field, I might mention one of some importance to the state of Florida.

A correspondent writes as follows:

> An odor which I am particularly interested in overcoming is that contained in China wood or tung oil. This odor is reputed to be due to traces of valerianic acid. Methods have been patented for removing these odors by steam distillation, etc. However, the odor is not removed permanently as, due to oxidation over periods of time, the acids that supposedly cause this odor are split off from the glycerides and cause the evil odors. There then remains the addition of perfumes or pleasant-smelling substances to permanently mask these unpleasant odors. . . . The China wood oil is used on a household fabric and of course must contain no unpleasant odor.

Stinks, of course, have their practical uses as well as perfumes. In many instances, as employed, for example, by insects and various animals, they serve as weapons of defense; or emanations which seem mephitic to others may have powerful sex appeal to the particular organisms concerned.

In the closing days of the world war, we were using as a camouflage gas butyl mercaptan, which is the chief perfume component of the skunk's bouquet. Its purpose was to deceive the enemy and to cause him either to retire or at least to don his gas mask and thus reduce his fighting efficiency, because he never knew when this stink was being used to mask some deadly gas. Our own troops, on the other hand, knowing that the skunk gas itself was harmless, could ad-

vance through it with impunity and do their fighting without masks and with the assurance that before any killing gas was sent over with it they would be informed in ample time to protect themselves.

We have but to turn to nature to recognize the dominant rôle of odors. What would our northern forests be without the resinous fragrance of their conifers, or the ocean without its clean salty invigorating tang? Or, consider the unfortunate skunk, "one of the handsomest little animals you would want to see, but his good looks don't do him any good. He is an outcast from decent society; nobody wants him around; most people would go to any lengths to avoid him. And when you do get anywhere near a skunk, smell becomes the most important thing in life. It is a factor powerful enough to make you climb trees."

Why is it that the art of the perfumer is not taken so seriously as that of the musician, the painter or the sculptor? We teach our young people to distinguish musical sounds and color effects, harmony in music and in pictorial art, but the vast possibilities of artistic enjoyment provided in our wonderful olfactory endowment they are left to learn in the slow, unsatisfactory and casual school of practical experience, with the result that even our language lacks specific descriptive adjectives by which variations in odor can be accurately characterized in the same way that we can describe differences in color and in shade. There are masterpieces in perfumery, as in other arts, but those qualified to understand and appreciate them are few indeed. One of these old masterpieces of the perfumers' art is the famous Eau de Cologne.

While on this subject of the perfumer's art, I might call your attention to an amusing article, entitled "100,000,000 Guinea Pigs Can't Be Wrong," which appeared in the *Givaudanian* for October, 1933, part of which runs as follows:

> Recently Consumers Research, Inc., issued a bulletin on perfumes and cosmetics in general, and when discussing many well-known brands on the market selling for 50 cents, 75 cents and a dollar per unit, tried to show that the true value of these products was 3 cents, 5 cents and 15 cents per unit. The interesting part is that the Consumers Research, Inc.'s analysis is correct—in its way.
>
> One of these days we expect a pamphlet from Consumers Research, Inc., analyzing the value of the pictures hanging in the Metropolitan Museum of Art or in the Frick Galleries. There are many pictures there which were purchased for $5,000, $10,000, $50,000 or even $100,000 each. Consumers Research, Inc., will say:
>
> | | |
> |---|---|
> | Value of frames, for instance | $15.72 |
> | Value of canvas | 2.50 |
> | Paint used | 7.20 |
> | Total value | $25.42 |
>
> Although the above calculations may be correct, I feel sure that the Metropolitan Museum would not at all feel that way about the prices it paid for its paintings.

As Dr. Arthur Selwyn Brown remarks:

> The domain of olfaction is full of mysteries that are worthy of investigation. The manner in which moisture causes the odors of the essential oils in flowers and trees to escape into the air, and fascinate the insect world; the way in which a dog, a crow, a jackal or lion tracks its prey or finds a carcass; the manner in which bees, wasps and ants recognize members of their communities; the way a dog, purely by odor, determines whether a strange dog it meets is likely to be friend or enemy; the manner in which parasites find their hosts, or the reasons that butterflies and other insects have strong preferences for particular flowers and perfumes afford wide fields for study.

When this fascinating domain is more fully explored, we shall learn secrets of which we do not yet even dream.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE GREATEST STAR CATALOGUE

By Professor SAMUEL G. BARTON

DEPARTMENT OF ASTRONOMY, UNIVERSITY OF PENNSYLVANIA

A LOOK at the sky on a clear dark night gives the impression that the stars are so numerous that it would be a hopeless task to try to count them. This idea is expressed in Genesis 15:5, where we read, "I will multiply thy seed as the stars of the heavens and as the sand which is upon the seashore," and in Psalm 147:4, which says, "He telleth the number of the stars; he calleth them all by their names." Have the stars been counted? If the question refers to the stars visible to the naked eye the answer is yes, indeed. For a small sum a set of maps—star charts—can be purchased which will show the position of each star. The number of such stars, about 6,000 in the whole sky, is astonishingly small, and not more than 2,500 of these can be seen at any one time and place.

But if a telescope is used to reveal stars too faint to be seen with the naked eye the number of stars which can be seen is greatly increased with each increase in the power of the telescope. No one has determined the number of stars which have actually been seen with powerful telescopes. An elaborate program, however, is now being carried out in preparing a catalogue which will record the positions of an immense number of stars.

Soon after the great advantages of photography for mapping the sky were realized, an international conference of astronomers was called to meet in Paris in 1887 to discuss the possibility and advisability of charting the whole sky on a uniform scale by photography. Astronomers realized, as you soon will, that the project was far too large for any one observatory or country and that, if it was to be done at all, many must cooperate. Cooperation was necessary, too, because from no one observatory is the whole sky visible. This conference was the beginning of international cooperation in astronomy and led eventually to the formation of the International Astronomical Union, the present organization of the astronomers of the world.

This conference was attended by 56 astronomers, representing 19 different countries. After discussion they decided to prepare a catalogue giving the positions of all stars as bright as the 11th magnitude. An 11th magnitude star is only one hundredth as bright as the faintest star visible to the naked eye. They also decided to prepare a set of charts showing still fainter stars. They agreed that the photographs should be made with telescopes especially designed and made for this purpose with lenses 13 inches in diameter with a focal length of 11¼ feet. Such an instrument gives a good picture of a section of the sky two degrees square on an area of the plate 4¾ inches square. Since the moon is half a degree in diameter, the images of four full moons could be placed side by side on one plate. The charts are enlargements made twice the size of the original plates, that is, they are about 10 inches square. Officially, the whole project is known by the French title Carte du Ciel, but in English it is known as the Astrographic Catalogue and the Astrographic Charts. We are concerned chiefly with the catalogue.

After deciding upon this program 18

observatories scattered throughout the world volunteered each to take one of the 18 approximately equal sections into which the work had been divided. France took four sections, Great Britain three, Australia and Italy two each, and Argentina, Brazil, Chile, Germany, Mexico, Russia and Spain one each. The United States was represented at the conference by three astronomers, but did not volunteer and has not participated in the work. Some observatories have been unable to fulfil their promises and some changes have been made in the original assignments. Five languages are used in the catalogue, English, French, German, Italian and Spanish. As we now know, they were exceedingly optimistic in supposing that all the work would be completed in from five to ten years.

To get a photograph of a section of the sky the plate is placed at the focus of the lens of the telescope, and the telescope is then a camera. The lens must be one designed for photographic use. The larger the lens and the shorter the focus, the more quickly will any given star impress its image upon the plate. When the focal length is small, a large area of the sky will be shown on the plate and of course the scale will be small. In photographing the sky we have a choice—we can use telescopes which will record the whole sky on a few small-scale pictures showing large areas with little detail, or on many photographs showing smaller areas in greater detail, just as we can have a single map showing the whole of the United States or we can have maps of the same size showing single states or counties. The larger the scale of the plate the more accurately can the positions of the stars on it be determined. As the Paris conference decided to determine star-positions accurately it adopted a pretty large scale and designed the instruments accordingly.

Knowing the area of the sky shown on each plate and the total area of the sky, we can easily determine that at least 10,313 plates are necessary to cover the whole sky. But because of unavoidable and desirable overlapping of the areas covered by plates, 11,027 plates were actually used in photographing the sky once, involving a duplication of 6½ per cent. But as photographic plates frequently have defects, the conference had decided that another set of photographs should be made as a check, with their centers in different places, and consequently 22,054 plates were used in making the catalogue. An equal number is needed in making the charts. The enormous size of the undertaking is now apparent.

The total area of the plates used in photographing the sky once is equivalent to a single square plate 41½ feet on a side. If printed in the form of an atlas with pages the size of an ordinary typewriter sheet, 8½ × 11 inches, 2,660 pages would be required. The scale of the plates is equivalent to having the stars represented on a globe 23 feet in diameter.

The plates used are not ordinary photographic plates but are made of plate glass especially ground at the edges. The cost of the plates alone, for the catalogue only, has been estimated at from $8,000 to $10,000. They weigh nearly three tons. Three exposures of 6 minutes, 3 minutes and of 20 seconds, respectively, were made on each plate, the plate being shifted slightly between exposures. Counting 10 minutes for each plate the actual exposure time for the 22,054 plates amounts to 135 thirty-hour weeks or close to three years.

Obtaining the photographs, however, is but the beginning of the process. Each of these plates must be measured, that is, examined under a specially designed high-power microscope, and numbers must be assigned to each star to fix its relative position on the plate. The diameter of the star's image is also measured to determine the brightness of

the star. Professor Turner of Oxford tells us that the measurement of the plates of the section assigned to that observatory—1,180 plates, a little under 1,225, the average number for a section —required the services of four or five persons for about ten years, and that the printing of the catalogue for that section required another four years. This section of the catalogue consists of seven large volumes and gives 470,873 star-positions. Special efforts were made to get the work on that section done rapidly and economically; yet the catalogue for that section was not published until 1911. It was preceded by the Greenwich section only, in 1908, and that was 21 years after the Paris conference. In 1937 fifty years will have elapsed since the Paris conference. At present half of the sections of the catalogue are completed and published. The other sections are in various stages of progress, but some results have been published in each. Some are progressing rapidly, others have been virtually abandoned. It can scarcely be hoped that all will be completed by 1937, although pressure is being exerted. Financial difficulties are responsible for the delay, the world war of course being a great factor. Professor Turner in 1912 estimated the final cost of the catalogue at $2,500,000. Dr. Perrine, over the date September, 1932, wrote rather pessimistically: "After half a century of effort in which the resources of many of the principal observatories of the world have been lavishly expended, the work is far from completed. It is not possible to estimate with any degree of accuracy the cost of the work to date, but it cannot be less than ten million dollars gold." This includes both catalogue and charts. There is much doubt as to whether the charts will ever be published completely.

From the volumes of the catalogue actually published, embracing 11,000 plates from many scattered parts of the sky, I find that there are in the average 400 stars per plate, which indicates about 9,000,000 star images for all the plates. Considering that in making the plates the sky has been photographed twice and that there is a further duplication of 6½ per cent., but considering also that some stars have been recorded from one plate only, I estimate that the total number of stars represented will be about 4,500,000.

The whole astrographic catalogue will be equivalent to about 150 volumes similar in size to those of the Oxford section, or we might say to about 150 volumes of the size of those of the Encyclopedia Britannica, that is, to over six sets of the encyclopedia. This number of volumes would occupy over 13 feet of shelf space.

The catalogue gives us a record of the position of a great number of stars at a particular time. It can be used and is being used for statistical work on a variety of problems. I am especially interested in double stars, that is, stars very close together in the sky and presumably close together in space. Examination of the Astrographic Catalogue has enabled me to discover to date about 1,500 hitherto unknown double stars separated by 5″ or less. The catalogue will find its chief value, however, in the future. The solution of many important problems in astronomy depends upon a knowledge of the slow changes in the positions of the stars. One of our prized possessions is Bradley's catalogue, giving the positions of over 3,000 stars compiled from accurate observations made from 1750 to 1762. From these observations and those made on the same stars near the present time we are able to determine the slow motions of these stars accurately by reason of the long interval of time between the observations. At some time in the future, say 50 or 100 years from now, new photographs of the sky can be made and the motions of the stars in the present Astrographic Catalogue can be determined. We shall then know much more about the size and structure of the

universe. As present-day astronomers are greatly indebted to the astronomers of the past for their observations, we are under an obligation to the astronomers of the future, an obligation we hope to fulfil in the Astrographic Catalogue.

Although not designed primarily for that purpose the catalogue gives reliable information on the number and distribution of the stars. But the number of stars recorded is but a tiny fraction of the whole number. Even the plates for the Astrographic Charts made with longer exposures with these same instruments will show about 20 times as many stars. We can get a good idea of the number of stars by merely examining many small areas in properly selected parts of the sky as samples. Such selected areas have been examined with our most powerful instrument. The results show that an instrument as powerful as the 100-inch reflector at Mt. Wilson would reveal to the eye about 500,000,000 stars in the whole sky, and that photographs made with that instrument would show twice as many, that is, a billion, about 200 times as many as are contained in the Astrographic Catalogue, which has required over 50 years in preparation and which has cost millions of dollars. The astronomer's work is surely not near completion.

We feel certain that more powerful instruments will show more stars, although we do not know how many. Estimates can be made, however, based upon more or less secure foundation. A recent estimate assigns to our system of stars a mass equal to 170,000,000,000 times that of the sun, which is an average-sized star.

NUCLEUS AND COSMOS

By Dr. HENRY A. BARTON

DIRECTOR, AMERICAN INSTITUTE OF PHYSICS

LADIES and Gentlemen, if you are so kind as to listen to my talk, I can assume you are interested in what is the latest news in the science of physics—what are the things now coming to light, the discoveries which are important in forming the knowledge of mankind and which are likely to make the world different for you and for your children. Of course, no man is clever enough to predict just how fundamental discoveries will finally take practical effect. We only know from past experience that our deepest glimpses of nature usually lead to the most revolutionary advances. For example, it took a very penetrating mental eye to discern the atom in the depths of ordinary bulk matter, but the same light that disclosed the atom has since rapidly revealed all modern chemistry.

The improved vision of physics now goes deeper even than the atom and we have the right to draw many conclusions concerning the atom's inner construction and behavior. In particular, we have reason to believe that the atom has a heavy compact center or kernel which is surrounded by a kind of mush composed of electrons. It is something like a plum. It would, however, be no more reasonable to stop the story at this point than to stop the story of the plum with the kernel. We naturally ask what is inside the kernel and it is just what we know about the atomic kernel—or nucleus, as it is called—that I want to talk about, and a little about how it is found out. You will admit that this is looking pretty deep, and you can accept the assurance of every physicist that big things will come of these small ones.

The first man to become interested in the atomic nucleus was a Frenchman, Becquerel, in 1896; but it remained for

Ernest Rutherford—now Lord Rutherford—first to grasp the concept of the nuclear atom, the atom like a plum. His idea was not in any sense a guess but rather an interpretation of his own careful experiments. Becquerel discovered the rays of radioactivity, and his work was quickly extended by Madame Curie and her husband. Rutherford and others showed in 1911 and the next few years that the rays came from the nucleus, not from the outer "pulp" of the atom. All the properties of these rays—their nature, their intensity, speed, etc.—immediately became the bearers of information about the object—the nucleus—that sent them out.

It has been shown that there are three kinds of radioactive rays: the electrically positive, the electrically negative, and a kind that is neither. The positive rays are called alpha-particles and they go very fast, the negative rays are electrons which go even faster and the others are like very penetrative x-rays, which, being a kind of light, go as fast as light—which is as fast as possible. Alpha-particles are going 12,000 mi./sec., beta-particles almost (but not quite) as fast as the x-rays, and the latter 186,000 mi./sec. Alpha-particles have been identified as the kernels of helium atoms. The beta-particles turned out to be electrons—in no way different from the electrons dancing to your bidding in the tubes of your radio set—except that they are going very fast.

The upshot is that the nuclei have volunteered the information that they are in part made of electrons and alpha-particles. But that is not the last of it. About the same time, Sir J. J. Thomson and later Dr. F. W. Aston began weighing atoms by a very ingenious method. They were actually weighing the atomic nuclei—because it turned out from Rutherford's experiments that the pulp weighs practically nothing and the nucleus contains practically all the weight of the atom. Once the nuclear weights were known, it became possible to test whether nuclei were made up only of alpha-particles and electrons. Well, the idea could not be held for a moment, because on the chemical scale an alpha-particle weighs four units and there exist in nature atomic nuclei weighing 1 unit, 6 units, 7 units, 9 units, etc., which could not be made of unbroken 4-unit alpha-particles any more than 35 cents or a dollar and a half can be made out of unbroken bills. Some kind of a quarter was needed. I ought to have said that the electrons in the nucleus do not count because they are so light we can forget about their contribution to the total weight. On our analogy they would be much less than pennies, and even America's first great physicist, Benjamin Franklin, would not mind our ignoring them.

The one-unit nuclei I mentioned are hydrogen nuclei, usually called protons. They are the kernels of hydrogen atoms. This, by the way, will not be new information to those who have read in the papers about the discovery of a still heavier hydrogen weighing two units instead of one. Since the alpha-particles weigh just 4 times the ordinary hydrogen nucleus and the other atomic nuclei likewise all weigh simple multiples, it was natural that physicists came to think that all nuclei are built up really of protons and electrons—nothing else. But since alpha-particles seemed to be parts of nuclei it was supposed that the protons frequently got packed into alpha-particles and the nuclei were then made up of these packages plus one or more loose protons.

Unfortunately, only the nuclear weights suggested that protons were the bricks of the nuclear structures. There was no positive proof of it. The radioactive atoms never gave any hints by sending out single protons. Furthermore, the information gathering was limited by the fact that no attempt to attack or study the nucleus by artificial means

was successful. The nuclei volunteered information in the shape of the radioactive rays, but none of the accepted third-degree methods of the laboratory succeeded in forcing the disclosure of further information—not, that is, until 1919—23 years after Becquerel made the first discovery of a nuclear phenomenon.

In 1919, Rutherford—the same Rutherford—at last found out how the human race could do something to the smallest things in the world. He showed that when he let the alpha-rays from radium fall as bullets on nitrogen atoms, some of the bullets would hit the nitrogen nuclei and knock out the very proton bricks that physicists had suspected nuclei were made of. Rutherford applied all his intelligence and skill to the methods of a child—breaking up things to see what they are made of—and thereby made himself the world's first successful alchemist. Because in knocking out a proton from the nitrogen nucleus he changed that nucleus into a different kind—a different chemical kind of atom. It is interesting to realize that we are living in the age in which the goal of the alchemists, sought for many centuries, was finally attained.

What makes such experiments as Rutherford's so difficult is that only a very small fraction of the shots fired at atoms succeed in smashing their nuclei. Another thing is that radium is very rare, so one's supply of alpha bullets is extremely limited. This is why no very startling further progress was made for some years.

Then, three years ago, nothing less than a new fundamental constituent of matter was isolated—a thing now called the neutron. It seems that the story about the nucleus was incomplete. Chadwick, of Rutherford's laboratory, identified still another kind of ray coming out of nuclei. He found these new rays were emitted from the nuclei of certain light elements like beryllium, when they are bombarded by alpha-particles. The rays are particles—not anything like x-rays—but yet not charged particles like alpha-particles and electrons. They were neutral and so were called neutrons.

In 1932 yet another ray was discovered, this time by Carl D. Anderson, working with Millikan in this country. These rays were knocked out of atomic nuclei when the latter were struck by cosmic rays. More recently, it has been found that certain radioactive rays can eject them, too. They are just like electrons but with one essential difference—they carry a positive charge of electricity instead of a negative charge. If one were put in a radio tube it would back up or go in the opposite direction to the ordinary electron. They are called positive electrons or positrons for short.

So our list of nuclear building blocks has been revised. We now have protons, familiar negative electrons, newly discovered positive electrons and neutrons. The augmented list is a victory of physical discovery, but it is a defeat for the physicist in his aim to picture nature in terms of as few elements as possible. He has not rested under the sting of this defeat and now has reason to believe that the old proton was not an element after all but rather a combined neutron and positron. This reduces the elemental stuff of the nuclei to three kinds instead of four. Thus do physicists answer our original question: What is inside of the nucleus? Electrons, positrons and neutrons.

They are going on now to find out how these elements are arranged, how put together, to make nuclei. Again the wise-childish technique of breaking things up has come into use. Now, however, it is no longer necessary to use the scarce and expensive alpha-rays for bullets. Apparatus has been developed to generate high voltages, and these can be applied to huge vacuum tubes in such a way as to accelerate hydrogen and helium nuclei which have been stripped of their electronic pulp by laboratory

means. The result is fast particles as effective as those found in nature and much more abundant.

For example, Cockcroft and Walton—of Rutherford's laboratory again—built up an elaborate apparatus capable of accelerating particles with 600,000 or so volts. They used protons (that is, hydrogen nuclei) for bullets and shot them against a piece of lithium. Lithium is a mixture of atoms weighing 6 units and atoms weighing 7 units in the chemist's scale of atomic weights. During the bombardment they found that the lithium target was emitting rays of something more powerful than the fast protons which induced the effect. But these "new" rays turned out not to be new in nature. They soon were proved to be the same old familiar alpha-particles. But the result was tremendously new. The experiments went on. It was found that the alpha-particles came out in pairs, that each pair had energy of motion equal to 15 million volts—surprising facts, but ones that carry a suggestion of the most fundamental significance for the world.

What we apparently must think about the Cockcroft and Walton experiment is that frequently a proton struck and entered a Li 7 atomic nucleus. Then a kind of alchemical reaction took place and there were produced two alpha-particles out of the original striking proton and the struck nucleus. Furthermore, these alpha-particles actually shot out (or flew apart) with greater energy than was put in. Atomic energy was released. That energy locked up in the mass of the nucleus—of which you have heard it said that a spoonful of water contains enough to drive the *Leviathan* across the Atlantic—escaped.

I want to make this idea as clear as I can. Go back to more familiar things. Start with coal—ordinary coal being burned in a power house. The combustion converts chemical energy into heat. The boiler and the turbine convert this heat into the mechanical energy of a turning steel shaft. This drives a generator in which the mechanical energy is converted into electrical energy. Thus it is a very familiar idea that energy can exist in different forms and can pass from one form to another.

Einstein, in his theory of relativity, states that matter itself is a form of energy and suggests that the matter in a particle like a nucleus may be consumable, or convertible into another kind of energy. It is this energy of mass which is generally known as atomic energy, and it is very concentrated. The idea has been a plaything for imaginative people, but the experiment of Cockcroft and Walton brings it down to the solid ground of actual human experience. For the amount of energy of motion in the two flying alpha-particles was exactly the amount it should be. That is, the proton and the lithium nucleus weighed just a little more than the two alpha-particles. Taking the difference in mass between the reacting materials and the products of the reaction, Cockcroft and Walton found that the energy of mass set free is just enough to produce the energy of motion observed. It is reasonable to suppose that just as the ancients developed the production of heat from chemical reactions, just as James Watt developed the steam engine, and just as Faraday, Henry and others developed the dynamo, so Cockcroft and Walton have begun the development of a process equally significant to the human race.

The title of my talk was "Nucleus and Cosmos," and you will observe that I have left but a minute for the latter. A minute to talk about the universe! But you see from what I have said that the nucleus is of cosmic importance. In fact, the cosmos is mostly made of nuclei, almost all the energy in the universe is in the nuclei, and even the

famous cosmic rays are almost certainly some kind of nuclear phenomenon. Probably in the hot cores of the stars, there does not exist any matter as we know it, no plum-like atoms. The pulp is burned away and nothing is left but bare kernels, neutrons and free electrons, striking up against one another in inconceivably violent agitation. There is no ordinary chemistry—only the kind of chemistry that Cockcroft and Walton found, nuclear chemistry or alchemy. The experiments of the last few years have assured us that man will be able to investigate—by his own efforts—the nuclei of the atoms. It is perhaps not too much to say that the field just opening and now definitely in view is larger than the field of all physics from the beginning of history to now.

NEW CROPS FOR THE AMERICAN SAHARA

By Dr. WALTER T. SWINGLE

PRINCIPAL PHYSIOLOGIST, BUREAU OF PLANT INDUSTRY, U. S. DEPARTMENT OF AGRICULTURE

To most people the word Sahara brings to mind a sandy desert waste, difficult if not dangerous to traverse because of the scarcity of water, and rendered doubly dangerous by blinding sand storms caused by hot, dry winds. However, all travelers agree that, wherever water is available in Saharan regions, there are found oases that show luxuriant vegetation, abundant production and picturesque beauty. More and more is being heard about these attractive features of desert life.

Few persons, however, realize that in the United States we have large areas which have climates that are extremely similar to those found in some of the best known parts of the Sahara desert and that in these sections of our country are to be found, as well, some of the most productive areas of the United States, regions which, thanks to irrigation, rival if they do not excel the finest oases of the Sahara itself in beauty, charm and in the bountiful production of human food.

Few people realize that no other populous, highly organized, temperate-zone country includes within its borders such large areas with typical Saharan climates through which are scattered, wherever water is available, magnificent productive oases. The Old World countries, France, England, Spain and Italy, possess, it is true, colonies which have Saharan climates, but none of them have within their own borders Saharan climates such as are found in the United States.

The North European settlers who live in these distant Saharan colonies, all but a few of them, move out en masse to cooler regions as the torrid heat of summer comes on, and the few who remain behind, in lonely isolation, to hold vital posts, do not have the proper attitude of mind to conduct scientific work or even to study critically and improve cultural practises. The natives of such Saharan oases who do live there the year 'round, are not qualified by disposition, nor by training, to question the time-honored practises of their forefathers, much less to make any scientific observations.

In no part of the world other than the United States do North Europeans reside the year 'round in large numbers in these Saharan climates. There are doubtless many more residents of North European ancestry in the hot valleys of Arizona and California than in all the rest of the Saharan climatic regions of the world put together. Many of these

residents of the oases of our Southwestern States are expert plantsmen, skilled engineers and some of them are high-school, college or university graduates. Thanks to this unusual situation, the study of desert crops and their culture in this country has made remarkable progress in recent years.

The culture of the date palm, one of the most characteristic and most beautiful of the crop-plants of the Old World oases, was undertaken early in this century as a definitely planned study to determine the possibility of introducing into the United States the crops of the Old World Saharan oases. This program was initiated by importing a large collection of the best date varieties of the Old World and planting them in several testing gardens in Arizona and California in cooperation with the state agricultural experiment stations of those states. Since then the date palm has been studied in the United States as nowhere else in the world.

Repeated trips to the date regions of the Old World, made by date experts under the auspices of the Division of Plant Exploration and Introduction of the U. S. Department of Agriculture and by private nurserymen, resulted in bringing into this country the best date varieties of all the leading date-growing regions of the Old World. Each date-growing country of the Old World has, to be sure, its own varieties of dates, but no country, other than the United States, has such a complete collection of the choice varieties of all countries, including well over one hundred date varieties from various parts of the Old World. These have been secured from the oases of Northern Africa, Egypt, Arabia, Mesopotamia, Persia and Baluchistan, and are now being tested in the experimental date gardens of California, Arizona and Texas.

Date culture has already become a promising new industry in California and Arizona, and some of the date gardens in these states are probably the best managed and give the highest yields of any in the entire world. The American public is coming to appreciate the delicious home-grown dates that are packed for the consumer, in an extremely clean and attractive way, practically fresh as picked directly from the trees.

The date palm can not be grown successfully except in a Saharan climate. There is an Arab proverb, which states that the date palm must have its head in the burning fires of the sky and its feet in running water. In the rich soils of southeastern California and southern Arizona, the date palm grows with extreme rapidity and comes promptly into bearing. No other commonly grown crop yields any such quantity of human food as the date palm, and the fruits are of such choice flavor and of such attractive appearance that they are almost to be classed as confectionery rather than as ordinary food. Besides, the exceptionally high and well-balanced mineral content of dates seems to render them an exceedingly healthful food—even for children and invalids. At the present time about four or five million pounds of dates are produced each year in the southwestern states, while about forty to fifty million pounds are imported into this country from the date-growing lands of the Old World.

As would be expected, American date growers and their technical advisers have made one discovery after another concerning date cultivation and production until it is no exaggeration to say that more progress has been made in improving date culture in the United States during the past twenty years than has been made by Old World date growers in the past twenty centuries. New methods of planting and of transplanting date palms; new methods of pruning them and of thinning the crop; new methods of picking, curing, sterilizing,

packing and storing the fruit, have not only been discovered but have been put into practise by intelligent American date growers. In the field of pollination of the flowers in particular, new and spectacular discoveries have been made.

People not familiar with the date palm may not realize that the pollen is produced on male palms which yield no fruit. In remote antiquity, some five or six thousand years ago, the Sumerians in Mesopotamia discovered how to pollinate the female date palm by tying a short spray of male flowers in each flower cluster of the fruiting palms. Only two or three male palms are needed for a hundred fruiting palms, and to-day all the Arab date growers of the Old World, as well as all the American date growers, practise this system of artificial pollination. This is a great advantage over the haphazard pollination of date palms growing in a wild state, where the wind blows the pollen about from the male palms to the fruit-bearing ones, which exist in about equal numbers when grown from seeds as date palms originally were grown.

The discovery about pollination which has come as a surprise to fruit growers and to scientific botanists the world over is that the pollen from different male palms has been found to exert a very definite influence upon the time of ripening of the fruit.

In some parts of the Southwest the summers are so hot that most date varieties ripen too early and tend to shrivel in the burning heat of later summer. In other regions the summer heat is not adequate to ripen all the crop before rainy cool weather begins in autumn, with the result that often a large fraction of the crop may hang on the palms in an immature condition far into the winter, with heavy losses from rain, which is very detrimental to the ripening of the fruit. By using the pollen from selected male palms it has been found possible to control ripening in an exceedingly satisfactory way, and this control is now being used on a commercial scale in some of the large date plantings in the Coachella Valley in Southern California.

There are thousands of beautiful date palms growing in the vicinity of Palm Springs, Calif., and Phoenix, Ariz., two of the most famous and most beautiful desert resorts in America, and these have attracted the enthusiastic admiration of great numbers of winter visitors. It is no exaggeration to say that the date palm has contributed more than any other cultivated crop to the beautification of the landscape; and furthermore, date gardens lend a characteristic desert atmosphere that nothing else could give.

The skilled Arab cultivators of the Old World plant, under the half-shade cast by the feathery foliage of the date palm, choice fruit trees of all kinds—oranges, figs, apricots, etc.—which thrive to perfection; and underneath the deeper shade of these fruit trees, sheltered from the burning sun, grow flowers and vegetable crops, thus making the land support willingly three tiers of crops—first, the leafy palms high in the air, then the friendly fruit trees, having their laden branches within easy reach, and finally, below them, vegetables, berries or lovely flowers. Our own date growers have already discovered that oranges, grapefruit and other citrus fruits thrive unusually well under the shifting half-shade of the date palm. Soon we too may expect to see luxurious gardens under our own lofty date palms, rivaling or excelling in charm those of the famous oases of the Old World.

PROTIUM—DEUTERIUM—TRITIUM
THE HYDROGEN TRIO

By Dr. HUGH S. TAYLOR

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THREE months before the outbreak of war in 1914 an international scientific race had just been concluded. Soddy of Aberdeen had found that radio-lead from thorium sources had an atomic weight of about 206. Richards and Lembert in Harvard and Hönigschmidt in Vienna had shown independently that radio-lead from uranium sources had an atomic weight of about 208. Ordinary lead was known to be about 207. Soddy's concept that substances could exist with identical, or practically identical, chemical and spectroscopic properties but different atomic weights was established. Soddy suggested a name for such substances, isotopes, because, though different in mass, they occupied the same place in the chemist's periodic table of the elements. We now know that isotopes of the same element have the same net positive charge on the nucleus and the same system of external electrons. It is the net nuclear charge, not the mass of the nucleus, which determines the position in the periodic table.

Aston, who after the war returned to the Cavendish Laboratory in Cambridge, England, developed a mass spectrograph to determine masses of individual charged particles and in November of the year 1919 supplied definite proof that the rare gas, neon, existed in at least two isotopic forms of masses 20 and 22. He thus extended the concept of isotopes to elements which were not radioactive in their origins. There followed a decade of activity in which, with the mass spectrograph progressively refined, an increasingly large number of elements were shown to be isotopically complex. There are, for example, eleven isotopes of tin. Some elements persistently proved to be simple. Carbon, oxygen and hydrogen were among those so regarded at the end of the ten-year period.

Early in 1929 the complexity of oxygen was established by Giauque and Johnston of California, using a novel method of attack, by examining the absorption of light by air. They found absorption bands which were interpreted as belonging to compounds containing two new oxygen isotopes, one of mass 18 and a much rarer one of mass 17. Oxygen, of mass 16, had been used as the standard of mass reference for all the other elements both for historical reasons and because of its assumed simplicity. Its established complexity at once raised doubts as to the simplicity of carbon and hydrogen. In the case of the former, the doubts were resolved by the discovery, in 1929, of a rare isotope of mass 13 by Birge and King, again from a study of the band spectra of gaseous carbon compounds, among others that of carbon monoxide. Birge and Menzel calculated that discrepancies between the chemical atomic weight and the mass spectrograph value for hydrogen would be resolved if hydrogen contained about 1 part in 4,500 of an isotope of mass 2. It was this theoretical calculation which provided the spur for an experimental search for such an isotope by Urey, Brickwedde and Murphy, jointly, at Columbia University and the U. S. Bureau of Standards. They announced early in 1932 that, by frac-

tional distillation of liquid hydrogen, the heavier isotope concentrated in the residue and that its presence could be demonstrated by the appearance of a faint spectral line in the hydrogen discharge near the ordinary line of atomic hydrogen and spaced from it at such a distance as would be demanded theoretically for an atom with a charge of unity (that is to say a hydrogen isotope) but having a mass of two.

Atomic weight determinations, mass spectrographic and light absorption measurements only demonstrate the existence, the relative abundance and the masses of isotopes. The practical identity of their chemical properties, emphasized at the outset by Soddy, had been utilized in the case of radioactive isotopes for chemical indicator purposes; the desirable goal of the scientist, the separation of the isotopes of an element and the separate examination and comparison of their properties, remained until a year ago unattained. An enormous amount of effort has been expended in the attempts at separation. These must be based on differences in properties which depend essentially on mass or on chemical reactivity. For a decade and a half prior to 1933 a variety of trials were made. Separation was attempted by fractional diffusion, by thermal diffusion, by centrifugal separation, by fractional distillation and evaporation at low pressure, by migration of isotopic ions under the influence of an electric current, by preferential excitation to photochemical reaction of one or other isotope using light absorbed by one and not the other. The net success was vanishingly small. One or other method gave separations of one or two parts per thousand at such a prodigious expenditure of effort that the recovery of the pure components of an isotopic mixture seemed to be an unattainable objective. The hydrogen isotopes, of masses 1 and 2, represent the most favorable case, since the mass difference is 100 per cent. Even in this case the problem seemed to be discouragingly difficult when it was shown that the fractional evaporation of 40 liters of *liquid* hydrogen until only two liters of *gas* remained raised the concentration of the heavier gas only to 1.5 per cent. Hertz in Germany has separated the two isotopes by fractional diffusion through special porous material to yield the separate constituents spectroscopically pure. His method, however, only yields a few cubic millimeters of gaseous product.

The development which revolutionized the whole subject of isotope chemistry is due to the late Dr. E. W. Washburn of the U. S. Bureau of Standards. Washburn determined, late in 1931, to test the efficiency of electrolysis of water solutions as a method of concentrating the hydrogen isotopes. While his own experiments were in progress, he secured samples of water from commercial cells which had been used for several years in the electrolytic production of hydrogen and oxygen. Urey analyzed this water for him by the spectroscopic method and found an enrichment of the mass 2 isotope. Washburn himself found that the density of the water was greater than that of ordinary water by 50 parts per million, a further evidence of enrichment. As Washburn and Urey wrote in their joint communication "the above results are of great importance, for we now know that there are large quantities of water in these electrolytic cells containing heavy hydrogen in relatively high concentrations and, also, there is available now a method for concentrating this isotope in large quantities." Washburn's determination of the abnormal density of water from electrolytic cells will take rank with those classical determinations by Lord Rayleigh of the densities of chemical and atmospheric nitrogen, from which,

with the work of Sir William Ramsay, there resulted the discovery of the rare gases of the atmosphere, helium, neon, argon, krypton and xenon.

The isolation of the mass 2 isotope in approximate purity was not achieved by Washburn. The race was to the swift and to those richer in available resources of apparatus and men. In rapid succession, from the University of California, Princeton, Cambridge, England, Columbia University, Frankfurt and Vienna came records of the success of Washburn's method in producing water in which with continued electrolysis 30, 60, 92, 99.9 per cent. of all the hydrogen atoms had a mass of two instead of one. Since the mass of the molecule H_2^2O would be $2 \times 2 + 16 = 20$, whereas ordinary water would be $2 \times 1 + 16 = 18$, it is evident that, granting equal volumes of the two molecules, the new water might have a density of $20/18 = 1.11$. The experiments were followed by the changing density of the product, and it is now known that heavy water with hydrogen of mass 2 has a density of 1.1079 at 25° C. referred to ordinary water at the same temperature.

Shortly after the isolation was accomplished, Urey, Brickwedde and Murphy christened the isotopes; hitherto this had not been necessary with isotopes since there had been no chemistry of separate isotopes to be considered. The discoverers of heavy hydrogen suggested, for hydrogen of mass 1, the name protium, since this would conform with current usage of the name proton for the nucleus of the hydrogen atom. For the isotope of mass two they proposed the name deuterium, which, for the nucleus of this atom, suggests deuteron or, more briefly, deuton, the nucleus of mass 2 and unit positive charge. They also suggested that, if the isotope of mass 3 were discovered, the name tritium might be considered. These names have found general acceptance, except in England, where, following a suggestion from Lord Rutherford's laboratory, the name "diplogen" has been employed. The best excuse for this latter is that it gives "diplon" instead of deuton, which latter does not find favor with the English scientists who, with colds in their heads in winter time, may confuse deuton with the "neutron" the particle of mass 1 and zero charge. Considerable discussion has arisen as to the symbols to be employed. Previous custom has sanctioned H^1, H^2 and H^3 for the symbolic representation. There is, however, an increasing use of H for H^1, of D for H^2 and of T for H^3. Fortunately, D and T have not hitherto been used as symbols for any elements; also, D stands, equally well in England and elsewhere, for both deuterium and diplogen.

For the technique of preparation of pure heavy water or deuterium oxide, the Princeton procedure may be cited, since, in this manner, about 13 tons of commercial electrolyte corresponding to upwards of 50 tons of ordinary water have already been treated to yield approximately one pound of the purest heavy water. About 15 gallons of commercial liquor are electrolyzed daily to one fifth volume in a battery of 960 cells using nickel anodes and iron cathodes. The residue is distilled to remove excess electrolyte, and the distillate after addition of alkali is passed to the second stage, a unit of 160 cells shown in the diagram, Fig. 2, on page 369, where it is again electrolyzed to one fifth volume. These two stages concentrate the deuterium from 1 part in 1,600 to 0.25 per cent., and 1 per cent., respectively. From the third stage onwards a modified form of electrolysis is employed in which the evolved hydrogen (containing deuterium) and oxygen gases are recovered as water and passed back to the preceding stage of electrolysis. The experimental arrangement is shown in Fig. 3. The

successive stages handle successively smaller volumes of water the concentration of deuterium in which rises by steps from 1 per cent. to 4, 13, 35, 95 and 100 per cent. D_2O. The electrolytic fractionation factor is about 5, that is to say, the gas evolved is about one fifth as concentrated in deuterium as the water from which it is evolved. Hence the separation that is achieved.

The product has unique and characteristic properties. Its density relative to ordinary water at 25° C. is 1,1079. It melts at 3.82° C. and boils at 101.42° C. It has a maximum density, not at 4° C. as with ordinary water, but at 11.6° C. It is 25 per cent. more viscous than ordinary water at 20° C. but has a smaller surface tension. Salts are less soluble in it by about 10 per cent., and the electrical conductance of salt solutions is less than in light water.

There are three kinds of hydrogen molecules that can arise from light and heavy hydrogen atoms, namely, H_2 molecules, D_2 molecules and the mixed molecule HD. To analyze mixtures of such gases a special mass spectrograph has been developed by Dr. Bleakney, of the Princeton Physics Department. It is evident that the molecules just discussed will give rise to ions of masses $2(H_2^+)$, $3(HD^+)$, and $4(D_2^+)$. In addition to these, atomic ions of masses 1 and 2 (H^+ and D^+) can also arise and, from these, triatomic ions (HHH^+) of mass 3, (HHD^+) of mass 4, (HDD^+) of mass 5 and (DDD^+) of mass 6. Bleakney's method permits him to sort out these various possibilities so that he can estimate how much protium (H) and how much deuterium (D) is present in a given sample. Fig. 1 shows the results of one such analysis of a deuterium rich sample.

Using such a method of analysis it has been found that the deuterium content of normal rain water is 1 part in 5,000 of the total hydrogen present. This is a much greater abundance of deuterium than is present in the chromosphere of the sun as spectra at the last eclipse definitely showed; it points to a tremendous preferential loss of light hydrogen during the earth's formation. The announcement by Lord Rutherford of the synthetic production of hydrogen of mass 3, tritium (T) by bombardment experiments of deuterium with high-speed deutons lent considerable interest to a determination by the Princeton Physics Department of the tritium content of the purest deuterium oxide water prepared in the Frick Chemical Laboratory. With a new and specially refined mass spectrograph it has now been shown that our purest heavy water contains approximately 1 part in 200,000 of the tritium atoms. This means that, in ordinary water, the tritium content is not more than 1 part in a billion. Tritium, therefore, becomes the youngest and rarest of all the isotopes yet discovered in natural occurring substances. Since heavy deuterium water costs, at a conservative estimate, $5 per gram, it is evident that, with a 100 per cent. efficiency of recovery of its tritium content, pure tritium water, T_2O, would cost at least $1,000,000 a gram or water roughly twenty times the cost of radium. Such are the paradoxes of modern isotope chemistry.

Using the same method of analysis it is possible to follow the rate of reaction of one isotope of a given element with its own isotope. It has been shown, for example, that H_2 molecules will react with D_2 molecules to form HD molecules at temperatures as low as that of liquid air, with catalysts such as chromium oxide and nickel which are active in catalytic hydrogenation processes. These results indicate that the high temperatures necessary in industrial syntheses such as those of ammonia or wood alcohol are required not for the activation of the hydrogen but for the activa-

tion of the molecules with which the hydrogen has to react. If surfaces can be found as active towards these molecules as present available surfaces are with respect to hydrogen, tremendous improvements would be possible in such industrial operations, under much simpler working conditions. Deuterium points the direction which research in technical catalysis must take.

Biologically, heavy water has proved to be of the utmost interest. Seeds of the tobacco plant do not germinate in heavy water. Fresh-water organisms such as tadpoles and guppies die quickly when placed in heavy water. Unicellular organisms, such as paramoecium or euglena, are more resistant, but are eventually killed. The luminescence of bacteria is modified in heavy water media, and the rate of respiration markedly reduced. Yeast ferments

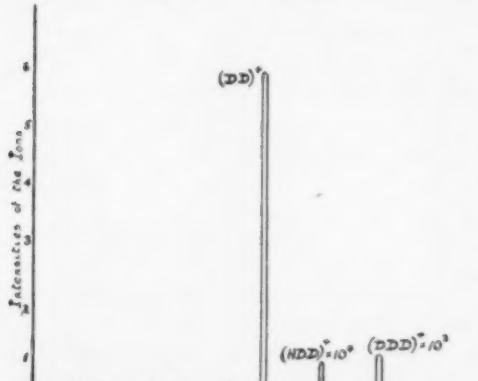

FIG. 1. DIAGRAMMATIC REPRESENTATION OF AN ANALYSIS BY THE MASS SPECTROGRAPH OF A GAS SAMPLE RICH IN DEUTERIUM. EACH PEAK REPRESENTS THE ABUNDANCE OF THE ION OF MASS GIVEN ALONG THE HORIZONTAL AXIS OF THE GRAPH. THE SCALE FOR THE IONS H^+, $(HH)^+$, $(HDD)^+$ AND $(DDD)^+$ IS MULTIPLIED BY THE AMOUNTS SHOWN AGAINST EACH PEAK TO PERMIT THEIR REPRESENTATION ON THE SAME DIAGRAM IN SPITE OF THEIR GREAT RARITY. THE ANALYSIS YIELDS 98 ATOM PER CENT. D AND 2 ATOM PER CENT. H.

sugar in heavy water at only one ninth the rate in ordinary water. The enzyme catalase present in the blood stream and whose function it is to destroy hydrogen peroxide does so at only one half the normal rate in 85 per cent. heavy water. The action of the heavy water may be likened to that of a generally unfavorable environment leading to progressive changes in the cell. It would seem that the changes observed are the result of differential effects on the rate of biochemical reactions, examples of which have just been given in respect to enzyme reactions. The use of heavy water as an indicator of reaction mechanism in biological systems is evident from reports of recent English work in which it has been shown, by experiments conducted in heavy water, with organisms such as *B. coli* and *B. aceti*, that the present accepted mechanisms for their activity need to be modified in the light of results obtained with media containing deuterium instead of hydrogen.

The known compounds containing hydrogen are numbered in the hundreds of thousands. It is evident that an overwhelming program of research replacing hydrogen by deuterium is possible. Judiciously conducted, such a program will aim at the preparation of materials with which problems in physico-chemical science may be tested. There are already the beginnings of such a program to be recorded. A number of exchange reactions between heavy water and different substances have thrown light on the problems of mechanism involved. Thus, ammonia gas, NH_3, exchanges very rapidly with heavy water, D_2O, to give ammonia in which the hydrogen atoms are replaced by deuterium atoms to an extent depending on relative concentrations. In cane sugar, however, only about half the hydrogen atoms are readily replaced and these atoms are those present in the molecules as hydroxyl (OH) groups. Acetylene,

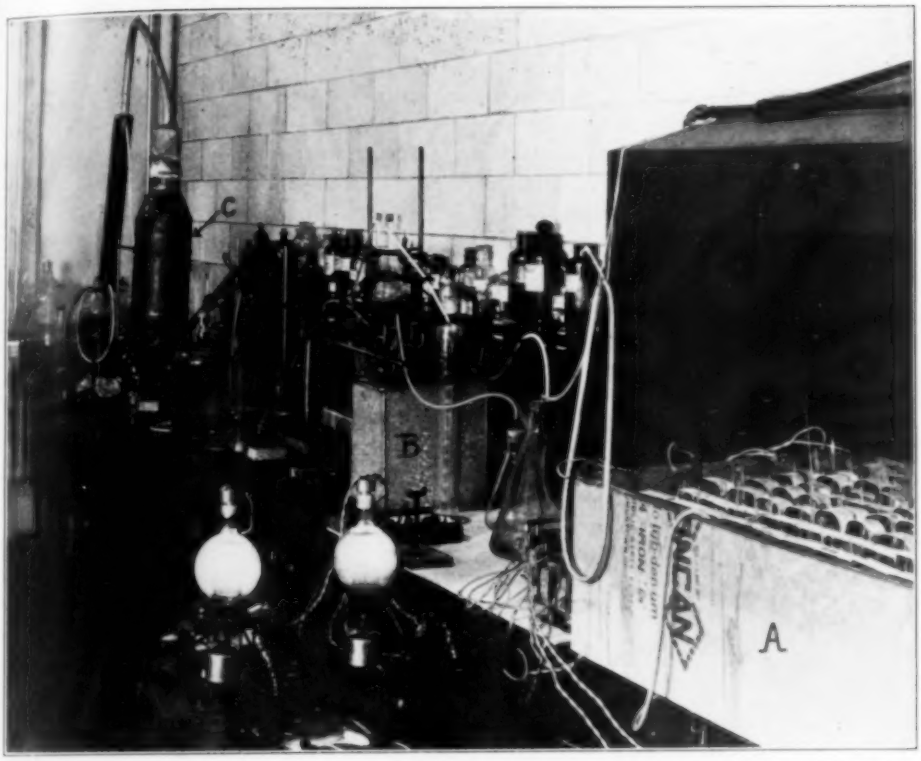

FIG. 2. GENERAL VIEW OF ELECTROLYTIC CONCENTRATION OF HEAVY WATER
TANK A TO RIGHT CONTAINS 160 UNITS FOR THE SECOND STAGE OF THE ELECTROLYSIS. TANK B, SHOWN IN DETAIL IN FIG. 3, IS A SMALLER UNIT, EMPLOYING RECOVERY OF THE EVOLVED HYDROGEN-DEUTERIUM MIXTURES AND USED FOR MORE CONCENTRATED SOLUTIONS. THE COPPER STILL FOR DISTILLATION OF ALKALINE LIQUORS IS SHOWN AT C.

C_2H_2, and acetone, CH_3COCH_3, do not replace their hydrogens for deuterium in acid solutions or in plain heavy water but do so more or less readily in basic solutions. The former exchange indicates definitely the acidic nature of acetylene. The latter demonstrates that acetone in basic solutions exists partially in another form $CH_2 . COH : CH_2$ which is acidic in nature due to the H attached to oxygen. In acetic acid CH_3COOH only the final acidic H is readily replaceable by D. In a compound such as nitroethane, $CH_3CH_2NO_2$, the two hydrogen atoms next to the NO_2 group are replaceable by deuterium in basic solutions of heavy water. In this case the rate of reaction can be measured and it has been shown that H atoms leave this molecule more easily in the heavy water solutions than they do in light water solutions. Similarly, cane sugar is broken up by reaction with heavy water faster than by light water. In other reactions the velocity is slower in heavy water. The accelerating or retarding effect obtained is used by the chemist to decide the detailed picture of what is occurring in such solutions. With deuterium atoms as labelled hydrogen atoms, much can be learned about these detailed occurrences; and what is found for deuterium must also occur with hydrogen under the same conditions,

even though, without the label, this can not be demonstrated. Reactions of deuterium and deuterium compounds which are slower than those of hydrogen are due to the fact that the lowest energy states (the zero-point energies) of the former are less than those of the latter. To become equally activated, by heat or light, deuterium must receive greater increements of energy; *vice versa*, under equal energy conditions the deuterium compounds will in general be less reactive. In cases where this does not hold it is to be concluded that reaction does not involve molecules of the deuterium compound, but rather an atom or an ion. Comparative velocity measurements are, therefore, of great importance theoretically.

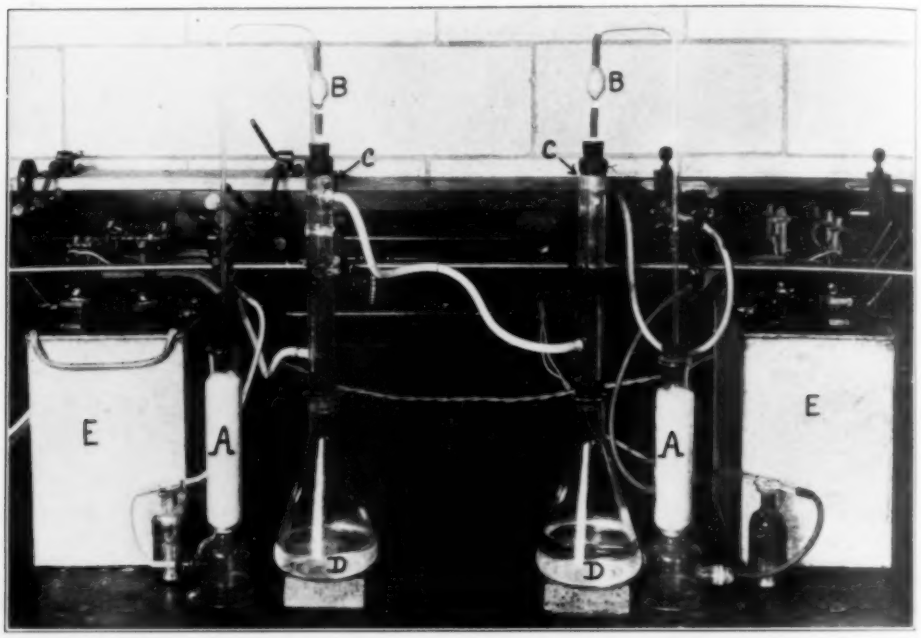

FIG. 3. ELECTROLYSIS WITH RECOVERY OF HYDROGEN-DEUTERIUM AND OXYGEN BY COMBUSTION AND CONDENSATION.

THE HYDROGEN-DEUTERIUM AND OXYGEN ARE FREED FROM SPRAY IN THE TOWERS A CONTAINING ABSORBENT COTTON, PASS THROUGH THE EXPLOSION TRAPS B AND ARE BURNED AT A PYREX JET C. THE WATER IS CONDENSED AND COLLECTED IN D, THE ENRICHED RESIDUE REMAINING IN THE ELECTROLYSIS VESSELS WATER-COOLED IN TANK E.

In the physics laboratory deuterium is being put to spectacular use as a projectile in atomic transmutation. Immediately after the isolation of deuterium the nuclei or deutons were so employed to bombard lithium, the results showing them to be much more effective missiles than protons. Two processes are possible with the isotopes of lithium of masses 6 and 7.

$$ {}_3Li^6 + {}_1D^2 = 2\,{}_2He^4 $$
$$ {}_3Li^7 + {}_1D^2 = 2\,{}_2He^4 + {}_0n^1 $$

The subscript to the left represents the nuclear charge; the superscript is the mass. Here also ${}_0n^1$ represents a neutron of zero charge and unit mass. Helium of mass 4 and charge 2 is the other product.

Experiments in Cambridge under Lord Rutherford suggested that deutons could be used to bombard deutons and

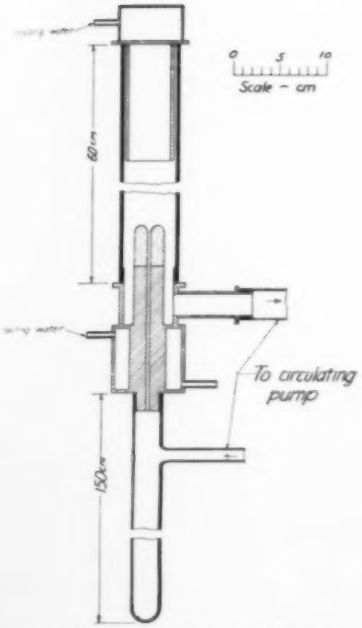

FIG. 4. DIAGRAMMATIC SKETCH OF TRANSMUTATION TUBE. DEUTERIUM IN THE UPPER HALF IS IONIZED AND THE DEUTONS ARE LED THROUGH THE SLIT OR CANAL, BETWEEN THE SHADED AREAS, TO THE LOWER HALF OF THE TUBE IN WHICH THEY COLLIDE, UNDER HIGH POTENTIAL, WITH DEUTERIUM ATOMS AND MOLECULES TO GIVE THE OBSERVED TRANSMUTATIONS TO TRITIUM AND TO HELIUM 3. THE GAS IS CONSTANTLY CIRCULATED BETWEEN THE UPPER AND LOWER HALVES OF THE CANAL RAY TUBE.

produce new forms of matter. Here, also, there are two possibilities.

$$ {}_1D^2 + {}_1D^2 = {}_1T^3 + {}_1H^1 $$
$$ {}_1D^2 + {}_1D^2 = {}_2He^3 + {}_0n^1 $$

In the first, transmutation gives two hydrogen atoms, one of mass 1, the other of mass 3, in other words, tritium. In the second, the change is to a helium isotope of mass 3 and charge 2 and a neutron of mass 1 and zero charge. Both of these changes have now been decisively demonstrated not only by the methods of Rutherford involving measurements of the tracks of particles; they have been employed to produce these rare isotopes "in quantity." Samples of deuterium after subjection to such atomic bombardment in apparatus shown in Figs. 4 and 5 have been found by the Princeton physicists to contain concentrations of tritium forty times greater than that of the deuterium initially. Similarly, the production of helium isotope of mass 3 has also been shown. In each case the method of analysis involves the sensitive mass spectrograph already discussed. Deutons also are being used as the projectiles for the production of artificially radioactive light atoms, the new field of physics developed only this last year by M.

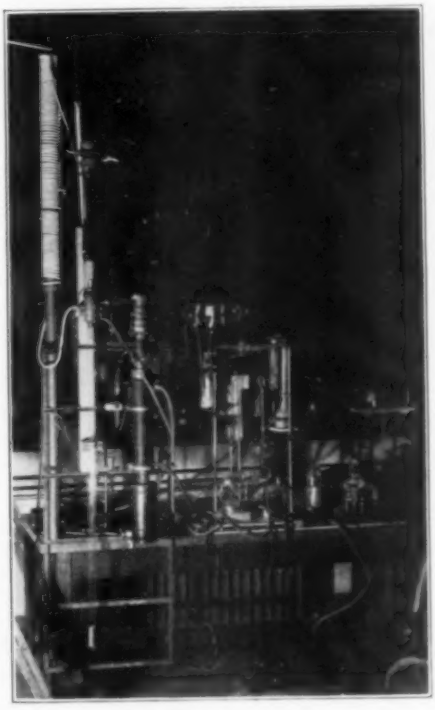

FIG. 5. GENERAL VIEW OF APPARATUS EMPLOYED IN PALMER PHYSICAL LABORATORY, PRINCETON UNIVERSITY, FOR TRANSMUTATION OF DEUTERIUM INTO (a) TRITIUM AND HYDROGEN, (b) HELIUM OF MASS 3 AND NEUTRONS. THE LONG GLASS TUBE SHOWN TO THE LEFT OF THE CENTER OF THE PHOTOGRAPH IS THE ACTUAL LOCATION OF THE TRANSMUTATION PROCESS. THIS UNIT IS SHOWN DIAGRAMMATICALLY IN FIG. 4.

Joliot and his wife, Mme. Curie Joliot, first with alpha particles, next with protons and neutrons and now also with deutons.

That the pace of this scientific development is prodigious all must realize when they remember that only one year ago the deuterium isotope was not yet isolated. To-day it has a still rarer brother, tritium; it has itself given rise to this and to other new isotopes, some radioactive, some not; it has made possible a new branch of chemistry, the chemistry of isotopes which already has markedly enriched our knowledge of general and physical chemistry; it is a potent weapon of attack also on physiological and biological problems.

CALENDAR REVISION AGAIN

By JOSEF J. JOHNSON

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MANY are the recognized defects of our present Gregorian calendar. Many are the suggestions which have been advanced to correct those defects and to provide a calendar which will meet modern needs as efficiently as possible. Yet comparatively little progress has been made toward the acceptance of a revised calendar, perhaps partly because of the inherent shortcomings of the various systems proposed and because of a peculiarly even balancing of these shortcomings as between rival systems. It is believed that the system here proposed, while by no means free from objections, will at least point a way out of the impasse which has arisen.

The history of the Gregorian calendar, its principal defects, the leap-year rule and the merits and shortcomings of the various proposed revisions have been so ably discussed in a recent article[1] by H. W. Bearce, of the Bureau of Standards, that it would be quite amiss to go into such matters here. Let it suffice to recall that the proposed revisions fall into two groups—the 13-equal-months plan and the 12-month-equal-quarters plan. The former, sometimes known as the "International Fixed Calendar," requires the intercalation of an extra month, for which the name "Sol" has been suggested. It has the obvious advantage of having all months alike; all evenly divisible into weeks. The latter plan, variously known as the "Swiss Plan" and the "World Calendar," lacks the advantages of the former but has the very real advantage of making the year easily divisible into equal quarters. Since the number of days in a year is not evenly divisible by seven, both plans require the insertion of occasional extra days, such as "blank days," "year days," "leap days" or double days—48-hour periods designated as one day and date.

There is some objection, principally on religious grounds, to the insertion of an extra day and the consequent interruption of the regular succession of the seven days of the week. But, as Mr. Bearce has pointed out, this objection must arise against any plan such that all years will begin on the same day of the week. If the objection is sustained, the case for calendar revision is hopeless. If it can be overcome, why not "go whole hog" and definitely part company with the seven-day week? Certainly, if the time was ever ripe for such a change,

[1] Henry W. Bearce, "The Proposed Revision of the Gregorian Calendar," SCIENTIFIC MONTHLY, 35: 500, 1932. For an able presentation of the merits of the 13-months calendar, see M. N. Stiles, "The Need for a Thirteenth Month," SCIENTIFIC MONTHLY, 39: 151, 1934.

it is ripe now. People who are accustoming themselves to a drastic revision in the length of the working week should be far less startled than as of old by the idea of a change in the calendar week.

Once we give up the seven-day week, our task is greatly simplified and many possible plans suggest themselves. The following is tentatively offered as a fixed calendar for every month of a 12-month year:

Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
1	2	3	4	5	6	
7	8	9	10	11	12	
13	14	15	16	17	18	
19	20	21	22	23	24	
25	26	27	28	29	30	31*

* Saturday the 31st to be counted in January, March, May, July and September of ordinary years; also in November of leap years.

The above system partakes of all the advantages of the "World Calendar," particularly of the divisibility of the year into halves and quarters—a point of great practical importance for statistical comparisons and computation of interest. It partakes also of the principal advantage of the "International" plan, namely, that, for every month, a given date falls always on the same day of the week. The months are, to be sure, not of exactly equal length; but it is to be pointed out that the apparent equality under the "International" plan is achieved only by means of the subterfuge of putting in an occasional day which does not belong to any month.

It will at once be objected that the plan here proposed would stand no chance whatever of being adopted; that the complete abandonment of the seven-day week is an idea far too drastic ever to be considered by the tradition-bound and custom-loving peoples of the earth.

Not so long ago the validity and finality of such an objection could not have been questioned. But many things have happened during the last few years—witness America's abandonment of the gold standard, the repeal of prohibition, the ———. The age of miracles is still with us. Why not a New Deal Calendar?

Charles W. Eliot

1834–1924

THE PROGRESS OF SCIENCE

AN APPRECIATION OF CHARLES WILLIAM ELIOT

PRESIDENT ELIOT of Harvard University was always a commanding figure, a center of attention, in any company of which he was a part. The fact that such a personality was still living, active in mind and body, capable of making an appropriate impromptu speech, at the celebration of his ninetieth birthday, March 20, 1924, lent to that occasion a dramatic interest which the recent centenary observance of his birth could not have in the same degree. But for that very reason the centenary offered perhaps an even better opportunity than the previous anniversary for a just estimate of the man and of his work.

He was an inheritor of the best New England qualities and traditions. He was energetic, practical and purposeful, capable of success in any business undertaking which might have attracted him. At the same time he was a moral idealist, a sincere Puritan, though without a trace of bigotry. He was a philanthropist who studied how to bring out the best possibilities in every individual whom his influence could reach. He was a deeply religious man, in faith and in feeling rather than in acceptance of dogma, and his devotion to the chief undertakings of his life was essentially a religious devotion.

Closely akin to his religious faith was his faith in human nature, his trust in the capacity, mental and moral, of the ordinary individual when properly appealed to. This had much to do with his famous predilection for the "elective system," almost free choice, for the individual college student among a great variety of courses offered. Admitting that some students would misuse this freedom, as some individuals will misuse any freedom, he believed this evil to be outweighed by the opportunity given for voluntary development of one's own best faculties and by the strengthening of character which the responsibilities of self-direction give.

If I had to characterize by a single word his conception of what education should be, I should choose the word *vital*. Teachers, he said in his inaugural address, should be young men or the kind of men who do not grow old. Education must be a quickening influence. It should bring the student into contact, the more intimate the better, with facts that interest him, that excite his curiosity, that cultivate his powers of observation and reasoning, that equip him for an active, useful and self-respecting career. Nothing should be taught or learned year after year merely because it had been taught or learned year after year. Moreover, education for any specific calling should be thorough. No man should enter the practise of any profession until he is as well qualified for that profession as he can reasonably be qualified for it by institutional training.

These propositions may seem commonplace now, but they were not commonplace sixty-five years ago, when Eliot became president of Harvard. If they are commonplace in America to-day, it is largely because his faith, his persistency, his power as a leader have made them so.

His leadership, contrary to the opinion which used to be rather prevalent among those who did not know him well, was not of the imperious kind. He sought always to persuade, not to subdue, or to repress discussion. He was proverbially a good listener, and it was partly for this reason, no doubt, that he was proverbially a good judge of the character and capacity of individual men. He had a large measure of freedom in the appointment of members of the various Harvard faculties, especially, perhaps, the Faculty of Arts and

Sciences, and he made appointments with much care, though not with a view to securing support for his own opinions. I once heard him say that one of the chief qualifications of a college president is the ability to recognize "the natural teacher and the real gentleman, sometimes under considerable disguises." The last four words of this quotation, saving the statement from being too flattering to a faculty audience, are, by the way, an excellent example of the always effective and always dignified humor with which his speeches and conversation were occasionally lightened.

In one of his informal addresses to undergraduates he said, in describing what traits distinguish a gentleman, "A real gentleman will always be considerate toward those whom he employs, toward those who might be considered his inferiors, or who are in any way in his power." As president he acted in accordance with this rule, but nevertheless an interview with him on a matter of business was for most members of the Harvard faculties something of an ordeal, as the following lines written by a professor many years ago will indicate:

> Don't be nervous, he will give you
> no unnecessary pain,
> As he deftly takes your cranium off
> and looks into your brain.

Such being the man, his aims and his methods, his work was fruitful. He maintained direct and active contact with every faculty of the university. By appointing more well-chosen teachers, by offering new courses, by extending the elective system, by infusing the whole with his own invigorating influence, he made of Harvard College a new institution, where men of learning and ability were glad to do their life work and where students gathered in increasing numbers. He recognized Langdell as the prophet of a new era in the teaching of law and placed him at the head of the Law Faculty, with results now known and acclaimed throughout the English-speaking world. In the Medical School, where shamefully loose and superficial methods of instruction had prevailed, he insisted upon, and against great opposition secured, a course of instruction and training commensurate with the responsibilities of the medical profession. The now famous Harvard School of Business Administration was founded in the later years of his presidency. In short, taking command of Harvard when the elder Agassiz, trained in Europe, declared it to be hardly worthy of the name university, he, in the course of forty years, made it one of the great institutions of learning in the world.

But he did more than this. He was public-spirited in the broadest way. He was actively interested in the primary and secondary schools of the country, and he exerted in various ways a stimulating influence upon them. His time, his thought, his experience were at the service of any college head who asked his advice, as many did.

He took an active part in the discussion of social and political questions, though he never had any political office and twice declined an offer of the London ambassadorship. Especially in his old age, after his retirement from the presidency of Harvard, he held a unique place as a venerated counselor of the American people.

As a speaker, whether in private or in public, President Eliot was remarkably effective. In look and manner he was quietly imposing, and in his later years benignant. His voice was at the same time mellow and powerful, always carrying and never seeming loud. He seldom indulged in flowers of rhetoric. He always seemed to be thinking his way along as he spoke, though he never hesitated, never needed to revise his sentences before publication. He once said, on the question of what constitutes a liberal education, that the only indis-

pensable requisite is a mastery of one's own language. This mastery he had, both in form and in substance, though he did not possess and he distrusted in others the gift of automatic eloquence.

EDWIN H. HALL

DECENNIAL REVIEW OF THE WORK OF THE MARINE BIOLOGICAL LABORATORY

AT the time of erection of the permanent buildings and of the establishment of the endowment of the Marine Biological Laboratory in 1923, a deed of trust was created, providing for custody of endowment funds; and, also, among other things, for a decennial review of its work. The purpose of these provisions was to ensure the continuation of management in the hands of American biologists, and at the same time to provide for expert administration of endowments. The membership of the Committee of Review provided for in the deed of trust consists of nine members to be nominated one each by the National Academy of Sciences, the National Research Council, the American Association for the Advancement of Science and by the professors in the field of biology of each of the following universities separately: Harvard University, Columbia University, the University of Chicago, Princeton University, Yale University and the University of Pennsylvania. The specific function of the Committee of Review is to ensure permanent protection of the purposes of the trust.

The committee met at the Marine Biological Laboratory on July 21, 1934, and made a study of its work as provided in the deed of trust, as a result of which they rendered a favorable report to the trustee on the work of the institution. Their meeting provides an opportunity

THE FAÇADE OF THE MARINE BIOLOGICAL LABORATORY.

THE TRUSTEES OF THE MARINE BIOLOGICAL LABORATORY AT THEIR ANNUAL MEETING IN AUGUST.

Top Row: M. J. GREENMAN, director of the Wistar Institute; CASWELL GRAVE, professor of zoology, Washington; E. NEWTON HARVEY, professor of physiology, Princeton; W. E. GARREY, professor of physiology, Vanderbilt School of Medicine; W. C. ALLEE, professor of zoology, Chicago; E. R. CLARK, professor of anatomy, Pennsylvania; LAWRASON RIGGS, treasurer of the Marine Biological Laboratory; D. H. TENNENT, professor of biology, Bryn Mawr; ROBERT CHAMBERS, professor of biology, New York University; C. C. SPEIDEL, professor of anatomy, Virginia; G. H. PARKER, professor of zoology, Harvard; FRANZ SCHRADER, professor of zoology, Columbia; H. B. GOODRICH, professor of biology, Wesleyan; B. H. WILLIER, professor of zoology, Rochester. *Bottom Row:* E. G. CONKLIN, emeritus professor of zoology, Princeton; H. H. DONALDSON, professor of neurology, Wistar Institute; W. B. SCOTT, emeritus professor of geology and paleontology, Princeton; CORNELIA M. CLAPP, emeritus professor of zoology, Mount Holyoke; M. H. JACOBS, professor of general physiology, Pennsylvania; F. R. LILLIE, professor of embryology, Chicago; GARY N. CALKINS, professor of zoology, Columbia; A. P. MATHEWS, professor of biochemistry, Cincinnati; W. R. AMBERSON, professor of physiology, Tennessee; CHARLES PACKARD, assistant professor of zoology, Columbia. *Middle Rows:* H. C. BUMPUS, Brown; B. M. DUGGAR, professor of physiological and economic botany, Wisconsin; L. L. WOODRUFF, professor of protozoology, Yale; C. R. STOCKARD, professor of anatomy, Cornell Medical College; R. S. LILLIE, professor of general physiology, Chicago; E. B. WILSON, emeritus professor of zoology, Columbia; T. H. MORGAN, professor of biology, California Institute; R. G. HARRISON, professor of comparative anatomy, Yale; L. V. HEILBRUNN, associate professor of zoology, Pennsylvania; FRANK P. KNOWLTON, professor of physiology, Syracuse College of Medicine.

to present to a wider public some aspects of the work of a unique institution.

It should, then, be recorded that the Marine Biological Laboratory was established at Woods Hole, Massachusetts, in 1888; and that from the start the management of its affairs has rested in the hands of American biologists on a co-operative basis. The members, numbering for many years over 300, elect a board of trustees composed exclusively of scientific men, who are responsible for the management. The high scientific reputation and stable membership of this board has ensured a consistent development of the institution.

The period under review by the special committee includes establishment of the endowment fund, the erection of the main laboratory, the establishment of a special library endowment and the erection of fireproof dormitories. Such events are not likely to be duplicated in the next decennium. They have naturally given a very important impetus to the work of the laboratory, but they have in no way altered its previously existing aims and purposes. During the last four years the general economic distress has been reflected in the laboratory by some reduction of activities; but, on the whole, the work of the laboratory has exhibited marked stability.

The number of investigators increased from 176 in 1923 to 362 in 1931 and fell off to 319 in 1933; the institutions represented by workers were 107 in number in 1923, 137 in 1931 and 120 in 1933. The total number of institutions represented in the decennium was 414, of which 95 were foreign institutions of learning. The development of the library has been very rapid and continuous: in 1923 the library contained 11,698 bound volumes and 9,587 pamphlets; in 1933, 37,420 bound volumes and 81,208 pamphlets. In 1923 journals currently taken numbered 281; and, in 1933, 1,137. A somewhat comparable development of research facilities and apparatus occurred during the same period.

The findings of the Committee of Review were to the following effects: that "the organization of the Laboratory, as embodied in its Constitution and By-laws, continues to operate effectively under the control of professional biologists. The Laboratory is especially well equipped for researches in general biology, experimental zoology and botany, embryology, physiology, biochemistry, biophysics and other branches of the biological sciences. Its research rooms, apparatus and facilities are excellent, and during the summer these are used to capacity. Living material for research is abundant and is promptly supplied by the Collecting (Supply) Department. The library is generally recognized as one of the best biological libraries in the country; it has increased about three-fold during the past decennium. It is freely accessible to investigators and is extensively used. General lectures and conferences are given at least twice a week throughout the summer session. They are largely attended and in general are very instructive and stimulating. One of the most important features of the Laboratory is the close personal association of workers in many fields over considerable periods of time. This is one of the chief attractions of the Marine Biological Laboratory."

The Marine Biological Laboratory serves the needs of all the universities, colleges and biological research institutions of the country, and offers its facilities to foreign institutions. It is a matter of general public interest that this institution, now in its forty-seventh year, through its unique form of organization, preserves all its pristine vigor and enthusiasm, owing to the fact that so many of the rising generation of biologists are drawn into membership. The control of its affairs thus changes

gradually and automatically, and the development of the biological sciences is always reflected in its membership.

The Woods Hole Oceanographic Institution, founded in 1930, has brought into the local scientific community a new strong group of workers, and has greatly increased the breadth of interests. Its location was determined largely by the reputation as a scientific center given to Woods Hole by the work of the Marine Biological Laboratory and the United States Bureau of Fisheries in its station established there since 1885. Mutual advantages accrue to these three institutions by their close association and cooperation.

FRANK R. LILLIE

PREHISTORY IN PALESTINE

PALESTINE'S place in prehistory and history runs parallel with its geographic position as a link in the chain which binds together the three continents of the Old World. Its prominent place in history and proto-history now bids fair to be equaled by its growing importance as a fertile field for prehistoric research. The attention of prehistorians was attracted to the Near East by Zumoffin's researches in caves on the Syrian coast near Beirut (1897); little was done, however, within the present limits of Palestine until after the World War. During the past dozen years much has been accomplished through educational institutions centered in Jerusalem in cooperation with and encouraged by the department of antiquities.

With Palestine as one of its prospective fields of operation, the American School of Prehistoric Research was founded in 1921. Our first opportunity to do some reconnaissance in Palestine came on the occasion of the International Congress of Archeology held in Jerusalem and Beirut in April, 1926. Prospecting at a number of prehistoric sites and examination of museum collections confirmed us in our previous estimate of the prehistoric possibilities of Palestine.

Exploitation of stone at the base of an escarpment in the Wady al-Mughara near the foot of Mount Carmel in 1928 accidentally brought to light two rare prehistoric carvings in bone. The site is less than six kilometers southeast of the Crusaders' Castle at Athlit (some 19 km south of Haifa). The discovery was reported to the Department of Antiquities, then referred to the British School of Archeology in Jerusalem. Miss Dorothy A. E. Garrod, representing the British School, then invited our school to join in the work of exploring and excavating that which turned out to be a group of caves, three of which have proved to be extremely important. The three productive caves are Mugharet el-Wad (Cave of the Valley), where the accidental discovery had been made, Mugharet es-Skhūl (Cave of the Kids), and Mugharet et-Tabūn (Cave of the Oven). The first two caves have already been completely excavated. The seventh season of excavations is now in progress and will complete the excavation of the third cave (Tabūn).

The sequence of cultures in the Mugharet el-Wad is remarkable for its completeness; the series, beginning at the top, is as follows: (A) Bronze Age to Recent; (B1) Upper Natufian (Mesolithic); (B2) Lower Natufian; (C) Upper Aurignacian of Caspian (African) affinities; (D) Middle Aurignacian; (E) Lower Middle Aurignacian; (F) Layer of erosion, containing both Aurignacian and Mousterian; (G) Upper Mousterian.

Many human skeletons were found in the two Natufian layers; numerous beads of dentalia shells and perforated animal teeth were found with some of these skeletons (Fig. 1). The Natufian deposits also yielded carved bone haftings set with microlithic flints (Fig. 8).

FIG. 1. HUMAN SKELETON
WITH CIRCLETS OF DENTALIA SHELLS ABOUT THE CRANIUM. MUGHARET EL-WAD. LOWER NATUFIAN EPOCH.

These were obviously used as sickle blades in the harvesting of grain. It seems therefore that agriculture had its beginnings as far back as the Natufian and antedates the potter's art; for no pottery has been found in Natufian deposits.

The Mugharet es-Skhūl deposit is of Lower Mousterian age. Theodore D. McCown of our school was in charge of its excavations. It was here that he found nine Neanderthal skeletons, the largest number ever found at a single site anywhere in the world. They were embedded in a breccia so hard that, in order to remove a single skeleton, it was in some cases necessary to cut out a block of stone weighing a ton. These blocks were sent to the Royal College of Surgeons, London, where McCown has been since last September superintending the extraction of the skeletons from the stone. The work is tedious and costly, but is facilitated through the use of an electro-pneumatic chisel and an electric dental lathe. The work of preparing these skeletons is still far from complete. The expense is being borne jointly by our school and the Royal College of Surgeons. The school's share of the cost is met through a generous grant from the American Council of Learned Societies. The University of California is contributing indirectly to the joint undertaking by awarding a fellowship to McCown.

The nine skeletons from the Mugharet es-Skhūl all belong to an early type of the Neanderthal race and furnish skeletal parts, which were missing in Neanderthal skeletons found previously in other parts of the world. The full sig-

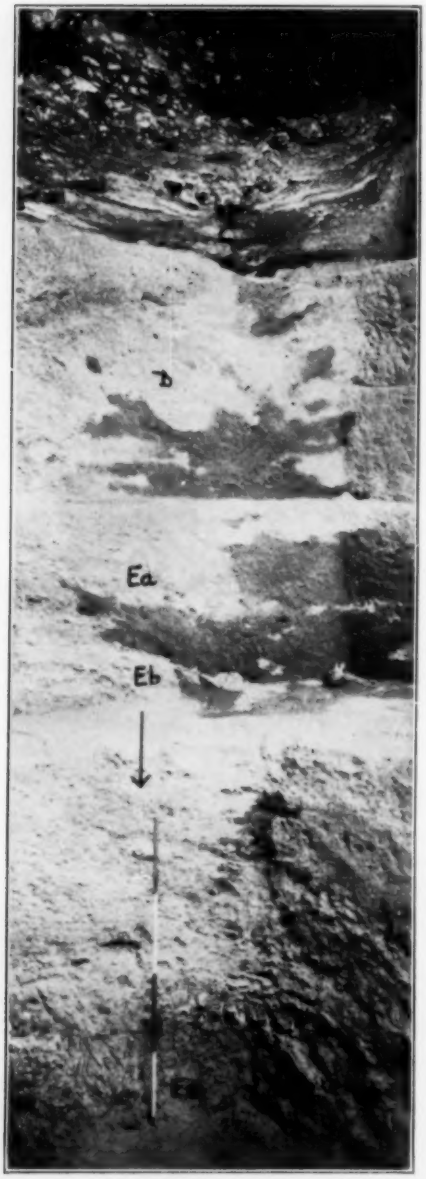

FIG. 2. CROSS SECTION OF CAVE INTERIOR OF MUGHARET ET-TABŪN (CAVE OF THE OVEN). ALL THE LAYERS ARE VISIBLE EXCEPT: A (BRONZE AGE TO RECENT), AT THE TOP; AND E (ACHEULIO-MOUSTERIAN) AND F AND G (ACHEULIAN AND TAYACIAN) AT THE BOTTOM.

nificance of this rich harvest from a single cave can only come to light after the bones have been disengaged from the rock, in which they were found. However, it is already obvious that the Neanderthalians of Palestine differed in several respects from those of western Europe.

The relic-bearing deposits in the Mugharet et-Tabūn are thicker and more extensive than are those in the other two caves, and man lived for a much longer period of time at Tabūn. Layer A at the top contains potsherds, which range from Early Bronze Age down to modern Arab. Mixed with these are a small number of Natufian flints. Below this come in turn: (B) Upper Mousterian, (C) Lower Mousterian, (D) Lower Mousterian, (E) Acheulio-Mousterian, a very thick layer with four distinct culture-bearing levels, (F) Upper Acheulian, and (G) Tayacian (Fig. 2). The deposits have a total thickness of 15

FIG. 3. FRONTAL BONE OF CRANIUM FROM LAYER C, TABŪN CAVE: (a) NORMA LATERALIS; (b) NORMA FRONTALIS.

FIG. 4. CHINLESS LOWER JAW

(UPPER)—LOWER JAW FROM LAYER C, TABŪN CAVE, RESEMBLING THOSE FOUND IN THE NEAR-BY CAVE OF SKHŪL. NORMA LATERALIS; (LOWER) —CHINLESS LOWER JAW OF THE SKELETON FROM LAYER C, TABŪN CAVE.

FIG. 5. LOWER JAWS

THE TWO LOWER JAWS FROM LAYER C, TABŪN CAVE. NORMA VERTICALIS.

meters and represent a time period of about 100,000 years.

In the upper portion of Layer C, Miss Garrod found the skeleton of a small adult female, with a low cranial capacity (Fig. 3) and a chinless lower jaw. Some 90 centimeters deeper in the same layer, she found the massive well-preserved lower jaw of an adult male, resembling the lower jaws of the skeletons found by McCown in the Skhūl cave (Figs. 4 and 5). In all these the chin is better developed than is usual among known Neanderthalians. There is also

FIG. 6. ARM BONE

LEFT UPPER ARM BONE (HUMERUS) OF THE SKELETON FROM LAYER C, TABŪN CAVE: (a) POSTERIOR ASPECT; (b) ANTERIOR ASPECT; (c) VIEW OF THE SIDE NEAREST THE BODY.

a difference between the limb bones of the Tabūn skeleton and the limb bones of those from Skhūl (Fig. 6). These differences represent extreme variations within the same race, combined of course with individual and sex variations.

Miss Garrod has prepared a composite section of the three caves in the Wady al Mughara (Fig. 7). It shows at a glance the absolute and relative thickness of the layers found in each of the caves, as well as how these layers overlap. The combined thickness, not counting repetitions, is 21 meters. In addi-

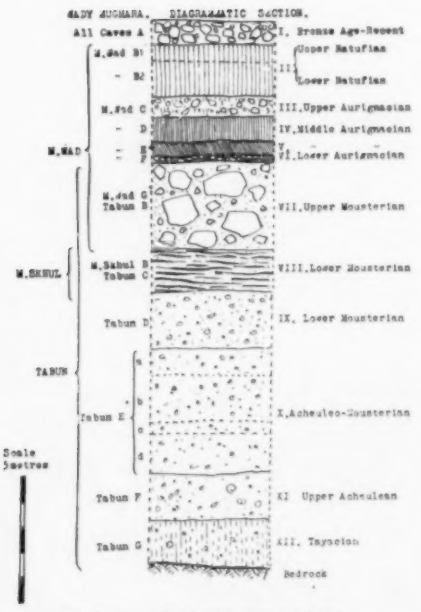

FIG. 7. CHART OF CAVE

COMPOSITE SECTION OF THE THREE WADY AL-MUGHARA CAVES; IT REPRESENTS A PERIOD OF AT LEAST 100,000 YEARS AND ITS THICKNESS, NOT COUNTING DUPLICATIONS OF LAYERS, IS MORE THAN 21 METERS.

tion to the record-breaking list of human skeletons, these various layers also yielded a rich harvest of cultural remains.

Our American School has likewise combined with the British School in the partial excavation of the Mugharet el-Kebara, near Zichron Jacob, some 16 kilometers south of Wady al-Mughara. As far as the excavation went (to the Lower Middle Aurignacian), the section revealed is not unlike that of the Mugharet el-Wad. The underlying deposit, not yet excavated, seems to be Mousterian. The most interesting layer is the Lower Natufian, corresponding to B2 of the Mugharet el-Wad. It yielded an abundance of bone implements, including very delicate harpoons with a single row of barbs and a splendid series of bone carvings, two of which are on the end of sickle blade hafts (Fig. 8). They are in the same class, only more complete, as these found in the Mugharet el-Wad. Mr. Turville-Petre, assisted by Mrs. Baynes, was in charge of the work in the Kebara cave.

A temporary exhibition of the results of the joint Palestine expeditions was held from February 1 to May 1, of this year, at the British Museum, through the courtesy of the trustees of the museum and the cooperation of Reginald Smith, keeper of the Department of British and Medieval Antiquities, and

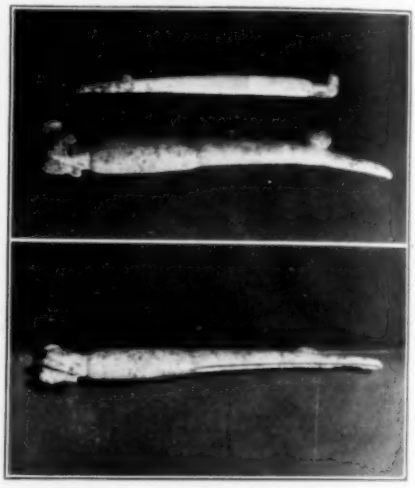

FIG. 8. SICKLE BLADES

TWO CARVED BONE HAFTINGS FOR SICKLE BLADES, COMPLETE EXCEPT FOR THE MICROLITHIC FLINTS, WHICH WERE SET IN THE LONGITUDINAL GROOVE SEEN IN THE FIGURE AT THE BOTTOM. MUGHARET EL-KEBARA. LOWER NATUFIAN EPOCH.

T. D. Kendrick and Christopher Hawkes, assistant keepers. Miss Garrod and Mr. McCown arranged the exhibition so as to include: (1) a complete sequence of the cultural remains from the Tayacian to the Natufian; (2) various animal bones from the different layers; and (3) some of the Neanderthal and Natufian (Mesolithic) skeletons.

GEORGE GRANT MACCURDY,
Director

AMERICAN SCHOOL OF
PREHISTORIC RESEARCH
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